

Innovative Water Resource Use and Management for Poverty Reduction in Sub-Saharan Africa

An Anthology

**With Introduction by
Paulos Chanie**



Organisation for Social Science Research in Eastern and Southern Africa (OSSREA)

VISIT...

LANZAROTE
Caliente.COM

Innovative Water Resource Use and Management for Poverty Reduction in Sub-Saharan Africa: An Anthology

With Introduction by

Paulos Chanie



**Organisation for Social Science Research in
Eastern and Southern Africa (OSSREA)**

© 2014 Organisation for Social Science Research in Eastern and Southern Africa
(OSSREA)

OSSREA acknowledges the support of Swedish International Development Co-operation Agency (Sida), Norwegian Agency for Development Co-operation (NORAD), and Danish Development Agency (DANIDA).

Published 2014

Printed in Ethiopia

ISBN:978-99944-55-75-1

All rights reserved.

Text layout: *Alemtsehay Zewde*

Organisation for Social Science Research in Eastern and Southern Africa

P.O. Box 31971, Addis Ababa, Ethiopia

Fax: 251-11-1223921

Tel: 251-11-1239484

E-mail: info@ossrea.net

Website: www.ossrea.net

Table of Contents

	About the Authors	iv
	Introduction	vi
1	Water Resources Use and Management for Poverty Alleviation in Gerado Irrigation Scheme, South Wollo, Ethiopia <i>Hassen Beshir</i>	1
2	Innovative Risk-Reduction Measures and Urban Welfare in Wastewater-Irrigated Agriculture: An Endogenous Switching Regression Approach for Nairobi, Kenya <i>Ezekiel N. Ndunda and Eric D. Mungatana</i>	43
3	River Based Agricultural Water Use Innovations in Uganda — Kabarole District: Opportunities and Challenges <i>Kirungi Jackline</i>	69
4	Approaches to Agricultural Water Utilization and Management for Poverty Alleviation: A Case of Makonde District, Mashonaland West Province, in Zimbabwe <i>Esther Sigauke and Rumbidza D. Katsaruware</i>	97
5	Harnessing Water for Poverty Alleviation: Water Resource Use and Management in Informal Irrigation Schemes in Nyamaropa Communal Lands, Zimbabwe <i>Krasposy Kujinga and Sunungurai Dominica Chingarande</i>	139
6	Innovative but not Feasible: Green Water Saving Schemes at the Crossroad in Semi-Arid Lands of Kenya <i>Chris Allan Shisanya, Cush Ngondo Luwesi, and Joy Apiyo Obando</i>	137
7	Drivers for Adoption of Water Harvesting Technologies Uganda nda With Reference to Lira District in Northern Region <i>Tobias Onweng</i>	177
8	The Role of Local Institutions in Water Use Management and its Implications for Poverty Reduction: The Case of Small-Scale Irrigation in Tigray <i>Fredu Nega and Sintayoh Fisseha</i>	207
9	Assessment of the Impact of Innovations in Water Resource Management on Poverty in Wakiso District, Uganda <i>Jamil Serwanga and Faisal Buyinza</i>	235

About the Authors

Chris Allan Shisanya holds a PhD in Agroclimatology and is a professor at the Department of Geography. He is Dean of the School of Humanities and Social Sciences, Kenyatta University, Kenya. His research works are in the areas of climate change and agriculture, integrated soil fertility management, integrated watershed management, and integrated sanitation management.

Cush Ngongo Luwesi teaches Geography, Economics and Development Studies in Kenyatta University and South Eastern Kenya University, Kenya. He holds a PhD and a MSC in Integrated Watershed Management. His research works focus on economics of water and climate change.

Eric Mungatana has a PhD in Environment and Natural Resource Economics. He is a Senior Lecturer in the Department of Agricultural Economics, Extension and Rural Development, University of Pretoria, South Africa. His research interests include natural resources accounting, non-market valuation, integrated ecological-economic modeling, water resources economics, and applied agricultural production economics.

Esther Sigauke has a MSc. in Environmental Policy and Planning. She is currently a lecturer in the Department of Geography and Environmental Studies and Programme Coordinator at Zimbabwe Open University. Her research interest is in the areas of waste management, conservation agriculture techniques, food systems and food security, climate change and variability, as well as water resources use and management

Ezekiel N. Ndunda has a PhD in Environmental and Natural Resource Economics and is a lecturer in the Department of Environmental Science, School of Environmental Studies, at Kenyatta University, Kenya. His research interests include environmental economics, resource economics, health economics, production economics and micro-econometrics.

Fredu Nega is a research fellow at the Horn Economic and Social Policy Institute (HESPI), Ethiopia. He has a PhD in economics and his research interests include poverty analysis, food security and economic growth.

Hassen Beshir holds a PhD in Agricultural Economics. He is an assistant professor and Head of the Department of Agricultural Economics at Wollo University, Ethiopia. He has done research on small-holder agriculture, poverty and technology adoption.

Jamil Serwanga has a PhD in Economics and is a senior lecturer in the Department of Economics at Zanzibar University, Tanzania. His research interests include poverty, rural development, as well as Islamic economics finance and banking.

Faisal Buyinza has a PhD in Economics and is a lecturer at the School of Economics, Makerere University, Uganda. He has done research on infant and child mortality, education, climate change, performance of manufacturing firms and related areas.

Kirungi Jackline is a PhD fellow at Makerere Institute of Social Research (MISR), Uganda. She has done research on gender and natural resources (land and water) development.

Krasposy Kujinga is a PhD candidate in Natural Resources Management at the Okavango Research Institute, University of Botswana. He has done research on water governance (policies, laws and institutions), water security, climate change adaptation, land and forests management, poverty and livelihoods and gender mainstreaming.

Rumbidzai Debra Katsaruware is a lecturer in the Department of Agricultural Management at Zimbabwe Open University. One of her research interests is low input crop production in smallholder farming.

Sintayoh Fissaha has a PhD in International Development Economics and is an assistant professor at Mekelle University. Her research interest is on aid, growth, poverty, gender, land, water, and food security.

Sunungurai Chingarande has a PhD in Sociology and is a Pro-Vice Chancellor at Zimbabwe Ezekiel Guti University. Her research interests are in the areas of gender, land reform and livelihoods.

Tobias Onweng is a Research Associate, Africa Leadership Institute, Kampala, and Director of the Food and Nutrition Security Directorate, Development Training and Research Centre (DETREC), Northern Uganda. He holds an MA in Rural Development. His research interests include food security, disaster mitigation and indigenous knowledge in agriculture.

Paulos Chanie has a PhD in Development Studies (2007) from the International Institute of Social Studies, Erasmus University, The Hague, Netherlands. During his career life, he has been teaching in Addis Ababa University, doing research and consulting local and international organisations in the areas of public policy and administration, development management, decentralisation and civil service reform. He has published in the areas of public service reform and management, ethnic politics, neo-patrimonialism, and fiscal federalism. He is currently an Assistant Professor at Addis Ababa University and Director of Research at the Organisation for Social Science research in Eastern and Southern Africa (OSSREA).

Introduction

Paulos Chanie

Like in many parts of the world, water resources in sub-Saharan Africa (SSA) have been pivotal for human survival, economic growth, social development, and practicing certain religion and cultural ethos. Water in this region is used for drinking, keeping hygiene and sanitation, irrigation, energy production, industrial use, transportation, but to mention a few. Water also shapes occupational and gender identities and relations at household and community levels in terms of beliefs, practices and division of labor. In many communities of the region, water use patterns reflect ideology and political beliefs about entitlement systems, rights and structures of communal or individual ownership; and play a significant role in indigenous beliefs, religious practices, rituals, songs and socialization activities. Moreover, water has been very crucial in the region's history, especially in its use in bridging gaps and contradictions in society, and even in inspiring people in their fight against colonial oppression as in the case of the 'Maji Maji' war against the Germans in Tanzania or more recently the 'Mayi Mayi' movement against oppressive regimes in the Democratic Republic of Congo. 'Maji' and 'Mayi' both mean water.

However, in spite of the intrinsic values of water, its use and management in sub-Saharan Africa has not been without limitations. In this region, the demand for water resources is increasing from time to time mainly due to rapid population growth, industrialization and urbanization. Dealing with water-related issues— especially with issues such as access to safe drinking water and sanitation; water use for irrigation, aquafarming, hydropower, industrial use, and transportation; water source maintenance and protection; water harvesting; and watershed management— has been complex and challenging for sustainable growth in the region. For instance, many coastal cities in SSA, which are endowed with potential alternative water transport systems, are dependent on road transport and incur heavy costs in terms of fuel, pollution, delays, accidents and environmental degradation. In addition, the abundant fishing resource in many of the countries in the region is exploited by foreign companies with little benefit to local communities. In general, weaknesses in the use and management of water are putting heavy pressure on overall economic and socio-economic development and threatening environmental sustainability. The failure to utilize water resources optimally and the limited contribution of water resources to poverty reduction in SSA is also reflected by the fact that for many poor communities water contributes to diseases and disasters more than to health, wealth creation and livelihoods. In these communities, even some of the destructive water weeds, such as the hyacinth, present a challenge while they should have been used, as is done in Vietnam, as raw material for making furniture or as manure of growing mushrooms and vanilla.

Whilst there are various efforts by national governments, non-government organizations and communities to effectively and efficiently utilize and manage water resources, there are few comprehensive studies in sub-Saharan Africa that show the impact of the efforts on poverty reduction. Although certain reports indicate that many SSA countries lack clear vision on how water use can be harnessed with pro-poor growth and how poor communities can be capacitated to use water for poverty reduction, there are little exhaustive studies that clearly show familiar and innovative water use and management interventions followed by communities, national governments and other stakeholders, and demonstrate the challenges and successes of the same.

Cognizant of the knowledge gap, in 2012 OSSREA launched a research project on ordinary and innovative water use and management patterns and practices in SSA, with a view to generate new knowledge on unexploited opportunities that could enhance the contribution of water resources to poverty reduction. The project aimed at making scientific assessments of the challenges and successes of ordinary and innovative water use and management systems in urban and rural communities; examining national and sub-national government policies, programs and projects that are put in place to enhance the use of water resources for poverty alleviation; as well as suggesting potential innovative strategies, policies and projects that can be put in place by communities, national and sub-national governments and other stakeholders to unleash the potential of water to contribute to poverty reduction.

In response to the call, 40 research proposals were received and reviewed, of which 12 research proposals were accepted for funding. Subsequently, OSSREA organized a research methodology training workshop on 'Innovative Water Resources Use and Management for Poverty Reduction in sub-Saharan Africa' for the 12 research grant winners drawn from 6 countries (Ethiopia: 3; Kenya: 2; Tanzania: 1; Uganda: 3; Zambia: 1; and Zimbabwe: 2). The workshop was organized to help grantees fine-tune their research proposals and refine their data collection and analysis methods. Out of the 12 accepted proposals, 9 were completed and submitted for publication. The authors of the completed research projects were requested to abridge their long research manuscripts and submit a 20 – 25 pages long chapter to be included in this manuscript entitled: *Innovative Water Resources Use and Management for Poverty Alleviation in sub Saharan Africa*.

This anthology documents various issues including water use and management in agriculture especially in irrigation projects in Ethiopia, Kenya, Uganda and Zimbabwe; water harvesting in Kenya and Uganda; the role of local water use institutions in Ethiopia; and water source maintenance and protection in Uganda.

The anthology constitutes nine chapters, the first five of which deal with water use and management in agriculture. The remaining four chapters

discuss issues of water saving; local water use institutions, and water source protection and maintenance. The following section summarizes the objectives and findings of each chapter.

Using the Gerado Irrigation Scheme, in South Wollo, Ethiopia, Hassen Beshir in Chapter One examines the role of irrigation development projects in achieving food and water security. The chapter argues that the scheme has improved farmers' production and consumption habits; access to market, education and health facilities; feed for livestock; and frequency of planting. It also allowed farmers to grow horticultural and high-value crops, to get sufficient water during dry seasons and to use motor pumps and utilize excess labour. The study also reports the major challenges of the case study irrigation scheme to be water shortage, fluctuation of prices, floods, pest infestation, frost, high price of inputs, water use conflicts, and lack of farmers' capacity and participation. It calls for the interventions of government and non-government organizations to address the challenges.

By collecting cross-sectional survey data from a randomly selected sample of 317 farm households and applying the propensity score matching model and an endogenous switching regression model, Ezekiel Ndunda and Eric Mungatana in Chapter Two analyze the effects of adopting risk-reduction irrigation technologies on consumption expenditure and crop income of urban and peri-urban farmers involved in wastewater irrigation in the Motoine-Ngong River basin in Kenya. The chapter argues that adopting risk-reduction measures in wastewater-irrigated agriculture has a significant impact on consumption expenditure and crop income per capita. It suggests that access to media, credit, and certified seeds; membership to farmers' associations; contact with local NGOs; and awareness on wastewater risks determine, albeit at varying degrees, the adoption of risk-reduction measures in wastewater-irrigated agriculture. The finding supports the emerging consensus that adoption of safer practices in wastewater-irrigated agriculture can enhance the welfare of many urban and peri-urban farmers in developing countries.

Chapter Three by Kirungi Jackline discusses river-based agricultural water use innovations in Kabarole District of Uganda focusing on River Mpanga. It elaborates three major uses of water from the river: 1) for irrigation during sunny seasons, 2) for mixing pesticides to spray crops and animals, and 3) for livestock drinking. The chapter also discusses the institutional framework for river-based agricultural water use; the equipment (jerricans, saucepans, perforated plastic containers, and watering cans) used by farmers to withdraw water from the river and transport to their gardens; the crops grown on the plots (cabbages, tomatoes, onions, green paper, bitter plants, eggplants, and Irish potatoes); the plantations along the banks of the river that are intended to reduce the chances of the river over-flowing and washing away gardens. The chapter argues that although river-based agricultural water use is positively contributing to agricultural production in

the case study area, it is not given the required recognition and support by national and district governments.

Chapter Four by Esther Sigauke and Rumbidza D. Katsaruware examines selected strategies employed by communities to ensure efficient utilization and management of water in agriculture in Makonde District, Mashonaland West Province of Zimbabwe. The strategies include: potholing, semi-circular furrows, mulching and manuring, drip irrigation, storm drains and canals, tank storing, and intercropping. It argues that the strategies have enabled farmers to increase their produce and obtain sufficient food for household needs, while also increasing their access to health and educational services. Challenges faced in pursuing the strategies include lack of access to credit and market, farmers' capacity constraints, and climatic uncertainties. The study suggests that government and nongovernment organizations need to train farmers and create to them access to credit facilities.

Collecting information from 249 farmers through structured questionnaires and conducting interviews with heads of relevant organizations, in Chapter Five, Krasposy Kujinga and Sunungurai Dominica Chingarande analyze the role of informal irrigation farming in enhancing livelihoods of farmers through food production in Nyamaropa communal lands found in Nyanga District, Manicaland Province, Zimbabwe. The chapter states that whilst the informal irrigation farming sector in Zimbabwe has an estimated area of about 20,000 hectares, it has no official and legal recognition by the state and that the country's law criminalizes it as many of those farmers use water without formal water use permits. The chapter argues that despite the activity being branded as informal and illegal, it plays a critical role in enhancing livelihoods and food security among practicing households. It, however, implicates that productivity and water efficiency under informal irrigation are greatly compromised by the use of traditional methods that use earthen canals and flood irrigation.

Drawing from a comparative analysis of the Ngusishi and Muooni catchments in the eastern region of Kenya, Chris Allan Shisanya and Cush Ngonzo Luwesi in Chapter Six document the extent to which Green Water Saving Schemes (GWS) are environmentally friendly, socially acceptable and economically viable. The chapter argues that GWS schemes are very crucial in determining the availability of blue water in streams, lakes and groundwater; involve close cooperation between upstream and downstream farmers; and are biophysically and technologically effective in controlling soil erosion and increasing soil moisture. It also discusses the hard and soft green water saving technologies found in the case study areas. The study, among other things, suggests the need to introduce a robust programme in response to hydro-climatic risks, including building farmers' capacity to upgrade existing GWS schemes and adopting innovative farming technologies to increase water productivity and water use efficiency in agriculture.

Chapter Seven by Tobias Onweng examines the types and uses of water harvesting technologies by farmers and factors influencing farmers' decisions to adopt the technologies in Lira District, Uganda. It states that the type of technologies in the case study areas include mainly furrow and ridge irrigation although there are also other technologies like drip irrigation, surface water tanks, underground water tanks and fish ponds. The water harvested is used for growing of crops, rearing of livestock and domestic use. The main drivers for adoption of water harvesting technologies included farmers' experience of the technology, perception of the characteristics of the technology (complexity, cost and benefits), and to some extent, potential for income. The main constraints affecting the adoption of the technologies are lack of labour and technical support. It suggests that innovative water harvesting methods that have been successfully adopted and used by farmers should be disseminated to other farmers in the district, and the country as a whole. Farmers should be financially and technically supported to adopt best technologies.

Using survey data collected from 310 sample households out of beneficiaries of three irrigation schemes (Haiba, Hizaeti Wedicheber and Rubafeleg) in Tigray region of Northern Ethiopia, Fredu Nega and Sintayoh Fisseha in Chapter Eight examines the role of local water use institutions in the management of water use and in enhancing community relations. Measuring the operation of Water User Associations (WUA) by the associations' role in participating farmers in cleaning and maintenance of irrigation canals, the chapter argues that the strength and functionality of the WUA have a significant impact on water use efficiency and productivity in the case study areas. It suggests that farmers' knowledge about the rules and regulations of WUA enhances their engagement in collective action especially in the cleaning and maintenance of irrigation canals. The chapter also argues that household income, and hence poverty level, is mainly affected by individual household characteristics, size of land irrigated and proportion of irrigated land used to grow vegetables rather than by the functioning WUA.

In Chapter Nine, Jamil Serwanga and Faisal Buyinza assess the determinants of innovations in water use and management for sustainable development in Wakiso District of Uganda, with specific reference to the sub-counties of Nansana, Kakiri and Nangabo. Using information from a survey of 299 households in the three sub-counties, the chapter, among other things, assesses cash and labour contributions for water source protection and maintenance. It argues that the willingness to pay cash and to contribute labour for water source protection and maintenance is influenced by sex and age of the household head, household size and income, convenience of location, participation during the service establishment stage, and advocacy activities by local councils. The chapter suggests that promoting participatory approaches, which fully involve beneficiaries according to their willingness and potentials, supported by the right advocacy and promotion efforts, can significantly contribute to

sustainability of water sources both in rural and semi-urban areas of Uganda.

In short, the nine chapters included in this anthology provide useful information which narrow the knowledge gap on the successes and challenges of water use and management systems in sub-Saharan Africa, especially on irrigation schemes, water harvesting programs, water source protection and maintenance techniques and roles of local water use institutions. The chapters are written based on case studies and data collected from surveys, interviews and focus group discussions, grey literature, and published journals and monographs. Various data analysis techniques are employed by the researchers including content analysis for the qualitative information and mathematical and statistical models for the quantitative data. The chapters provide evidence-based findings and recommendations. One of the recommendations that recurs across the chapters is the need for further research to have more insights and policy recommendations on enabling sub-Saharan African countries to utilize and manage their water resource for poverty alleviation.

Water Resources Use and Management for Poverty Alleviation in Gerado Irrigation Scheme, South Wollo, Ethiopia

Hassen Beshir

Abstract: The objective of the study was to examine dimensions of poverty and determinants of the use of water resources for poverty alleviation, in Gerado Irrigation Scheme, South Wollo. Qualitative and quantitative data were used and analyzed, using various descriptive and econometric techniques (Foster, Greer, and Thorbecke <FGT> model and Heckman model). The proportion of poor people was 47.2 per cent and 42.98 per cent, for non-irrigators and irrigators, respectively. Poverty profiles indicated that farming households that practiced small-scale irrigation were not as poor as households without irrigation. The findings showed that farm household asset formation, and provision of extension and credit services, were the main determinants in irrigation development and expansion.

Key words: Ethiopia, FGT, Gerado, Heckman, Irrigation, Poverty

1. Introduction

Agriculture is the mainstay of the Ethiopian economy. It provides employment for more than 85 per cent of the working population, accounts for 90 per cent of total exports, 42 per cent of the Gross Domestic Product (GDP), and is a major source of raw materials for the industrial sector (Ministry of Finance and Economic Development <MoFED> 2012). Ethiopia is characterized by diverse and complex farming systems. The diversity and complexity of farming systems is especially high in the northern part of the country where the Amhara National Regional State is situated. Amhara National Regional State is home to 17.2 million people (CSA 2008). The region consists of 11 administrative zones, of which South Wollo is one. Poverty is persistent across Ethiopia. Poverty reduction is the overriding goal of development programmes and the primary challenge facing the development community today. Despite dramatic global poverty reductions recorded in the last three decades, the number of poor people increased in Sub-Saharan African and South Asian regions. Among the Sub-Saharan African countries, Ethiopia has the highest number of food insecure people, and people who survive on less than a dollar a day (Tassew 2004). An estimated 52 per cent of the country's population is food insecure, with 44 per cent below the poverty line (Dereje et al. 2011). Growth in crop and livestock production is the main way out of alleviating poverty in Ethiopia.

Water, soil, air, and sunshine are the four main determinants for plant growth. Therefore, water is essential to plant growth and crop production (Widitose 2001). Water is a basic need for human beings and animals. It is essential for their metabolic processes. Water is vital for all types of agricultural production. Sources of water for crop production are rainfall and irrigation water (Dupriez and De Leener 2002). Irrigated cultivation is a form of agricultural production using irrigation water, in addition to rainfall. Irrigated crops benefit from man-made watering, with the help of water pipes, canals, reservoirs, and pumps. The source of irrigation water may be surface water or groundwater. Surface water is obtained from ponds, lakes, rivers, and seas whereas groundwater is obtained from underground, in liquid or vapor state.

Small-scale irrigation development is a policy priority for rural poverty alleviation and growth in Ethiopia (MoFED 2006) as well as for climate adaptation (GoE 2007). However, only around 5 per cent of Ethiopia's irrigable land was irrigated in 2006 (World Bank 2006) and less than 5 per cent of total renewable water resources were withdrawn annually (FAO 2005), hence there is considerable scope for expansion.

Ethiopia has a long history of traditional irrigation systems. Simple river diversion is still the dominant irrigation system in Ethiopia. The country's irrigation potential ranges from 1.0 to 3.5 million hectares but various studies indicate that the irrigation potential of the country is higher (Gebremedhin and Peden 2002). Estimates of the irrigation potential of Ethiopia may be as much as 4.3 million hectares (Awulachew et al. 2007). Amhara region has 770,000 hectares of irrigation potential (MOA 2005 and Awulachew et al. 2007). Different development activities have been underway to utilize these resources. Currently, there are 310 irrigation schemes operational in the Amhara region. The irrigation schemes developed cover an irrigated area of 8,469 hectares, with 17,443 beneficiaries; small-scale irrigation schemes account for 5,719 hectares and medium-scale irrigation schemes, 2,751 hectares (Getaneh 2011).

Irrigation user households reported an average 20 per cent increase in annual income since adopting irrigation, and in some cases, up to 300 per cent, due to cultivation of higher value crops, intensified production and reduced losses (Ripple 2010). Further, nutrition was said to have improved as various fruits and vegetables became locally available. Irrigation benefits the poor through higher production, higher yields, lower risk of crop failure, higher year-round farm and nonfarm employment, and enables smallholders to adopt more diversified cropping patterns, and to switch from low-value subsistence production to high-value market-oriented production (Hussain and Hanjra 2004). Hence, there is a direct relationship between using irrigation and poverty alleviation.

Gerado Irrigation Scheme was, for many years, traditionally used for irrigation by farmers. In 1996, the regional government had developed the scheme to irrigate 80 hectares. However, the scheme was used by more

than 1,228 farmers, to irrigate 250 hectares. Despite the various purposes of small-scale irrigation, the majority of small-scale farmers in the study area do not realize the potential benefits.

This paper provides results of a study conducted to describe and analyze existing and potential innovative approaches used by local communities, and examines determinants of the use of water resources for agriculture, taking the Gerado small-scale irrigation scheme located in South Wollo, Ethiopia, as a case study. Understanding the poverty reduction impact of irrigation development projects and analyzing innovative approaches in irrigation water management methods and approaches is important for charting sound policies, for future irrigation development. This paper deals with the water-food-poverty nexus and examines the role that sound and feasible irrigation use and management can play in achieving food and water security.

The major research questions were:

- (a) Who are the key actors and what role do they play in irrigation development?
- (b) What are the innovative approaches used by farmers to obtain higher production and increased income from irrigation?
- (c) What is the incidence, depth and severity of poverty, among irrigator and non-irrigator households in the study area?
- (d) What are the determinants of poverty reduction, with regards to impacts of using and managing water resources in the study area?

The general objective of the study was to assess innovative approaches in irrigation management use, and to examine determinants of the use of water resources for poverty alleviation in Gerado Irrigation Scheme. The specific objectives of the study were:

- (a) To assess the challenges and successes of existing irrigation water use and management systems;
- (b) To identify existing and potential innovative approaches in irrigation water management that are used by local communities;
- (c) To determine the incidence, depth and severity of poverty among irrigator and non-irrigator households;
- (d) To examine the determinants of poverty reduction, with regards to impacts of using and managing water resources.

The paper is organized into five sections. Section one constitutes the introduction, which focuses mainly on the background, statement of the problem and objectives of the study. Review of theoretical and empirical literature relevant to the paper is presented in Section two. Section three describes the research methodology, which includes a brief description of the study area, data collection procedures and analytical techniques. Section four presents reports on critical analysis of results of the study. Finally, a

summary of the major findings, conclusion and recommendations are presented in Section five.

2. Review of Literature

2.1 Review on Concepts of Poverty

Poverty definitions and measurement have important implications for targeting and policy purposes. The concept of poverty goes back to the 16th and 17th centuries (Getaneh 2011). Before 1750, there were four approaches to measure poverty: acceptance (resignation), charity, precarious rescue, and theft, depending on which side of the fence the observer stood. Since the era of Mercantilism, the fight against poverty has been evident. Consequently, it was with the advent of the Mercantile economy, and the urbanization and monetarization of society, that the poor have been defined in terms of lacking what the rich have (David et al. 1994).

Different scholars define poverty in different ways, and no attempt is made here to exhaust the definition. One possible definition is the inability to attain a minimum standard of living (World Bank 1990). Alternatively, poverty is defined as the scarcity of key resources to meet development objectives. Poverty is lack of basic human necessities, a condition arising largely from the absence, scarcity or underdevelopment of required resources or attitudes towards the utilization of resources (Edilegnaw 1997). Others, including Sen (1981), defined poverty as “pronounced deprivation in well-being”, and regarded it as both the presence of low-income and the lack of assets (education, health, adequate nourishment). From the multidimensional perspective, people are poor when their level of income does not allow them to buy the minimum amount of food required to perform daily duties and tasks, nor to obtain a minimum level of education, nor seek medical attention when necessary, that is, when they are not able to satisfy their basic needs (World Bank 2000). In fact, most of the literature on poverty uses terms such as income or consumption poverty, food poverty, human underdevelopment, social exclusion, lack of capability and functioning, vulnerability, livelihood unsustainability, lack of basic needs, and relative deprivation, to describe or define poverty.

Poverty could be measured using poverty lines. In the literature (for example, Ravallion 1998), different approaches have been used to define the poverty line. The food-energy intake approach defines the poverty line by computing consumption expenditures or income level at which a person's typical food energy intake is just sufficient to meet his/her predetermined food-energy requirement. If applied to different regions within the same country, the underlying food consumption pattern of the population group just consuming the necessary nutrient amounts will vary. This method can thus yield differentials in poverty lines in excess of the cost-of-living differential facing the poor. In this respect, the cost of basic needs method values an explicit bundle of foods, typically consumed by the poor at local market prices, first. To this, a specific allowance for non-food

goods, consistent with spending by the poor, is added. However, defined poverty lines will always have a high arbitrary element. For example, the calorie threshold underlying both methods might be assumed to vary with age.

The other approach used to define poverty line entails the use of monetary measures of poverty. In this regard, one may have a choice between using income or consumption as an indicator of wellbeing. Dercon and Krishnan (1998) used consumption expenditure as the basis for measuring the standard of living while studying changes in poverty in rural Ethiopia, from 1989 to 1995. Most analysts argue that, provided the information on consumption obtained from a household survey is detailed enough, consumption would be a better indicator for poverty measurement than income, for the following reasons: First, consumption is a better outcome indicator than income because actual consumption is more closely related to a person's well-being, in connection with having enough to meet current basic needs. Income is only one of the elements that allows consumption of goods (others include questions of access and availability). Second, consumption may be better measured than income given that poor agrarian economies, such as Ethiopia, and urban economies with large informal sectors, tend to have erratic income flows that fluctuate during the year. Third, consumption may better reflect a household's ability to meet basic needs, in that consumption expenditures reflect not only the goods and services that a household can command based on its current income, but also whether that household can access credit markets, remittances or household savings at times when current income is low or even negative, perhaps due to seasonal variation or harvest failure. Consumption can, therefore, provide a better picture of actual standards of living than current income, especially when income fluctuates a lot. McClelland (2000) indicated that poverty is a scenario where people have unreasonably low living standards compared with others; cannot afford to buy necessities, such as a food, for example; and experience real deprivation and hardship in everyday life. Empirical evidence shows that poverty rates vary when different concepts and measures are used. There are two types of poverty, absolute and relative poverty: absolute poverty is defined as the minimum amount of essential goods and services that a household needs, in order to survive. It is estimated based on the income needed to purchase these subsistence amounts. Relative poverty occurs when the household's standard of living falls seriously below what is believed to be normal, for the society in which they live (Ravallion 1998). In addition to its impact on poverty reduction, food security may be achieved through efficient management and use of irrigation.

2.2 Review on Impact of Irrigation on Poverty Alleviation

Various empirical works have been conducted in developing countries, on the impact of irrigation on poverty reduction. Bhattarai et al (2002) explored the conceptual and policy issues relating to the impact that

irrigation has on crop production, farm income, inequities in income distribution, and poverty alleviation. They mentioned that improved access to irrigation infrastructure will increase crop yields, agricultural production and farm income within Africa. They found out that improved irrigation access is a powerful instrument for reducing rural poverty in a given region.

Munawar (2004) assessed the impact of small-scale irrigation scheme on agricultural production and poverty in Pakistan. He found out that irrigated cultivation, improved seed variety, fertilizers, irrigation water, and pesticides had significant effects on crop productivity. His results indicated that the expansion of small-scale irrigation schemes had improved crop productivity and alleviated poverty.

Alam and Elias (2007) determined the impact of irrigation on farm households, using the Gini coefficient in Bangladesh. Their results indicated that the Gini ratio was higher for irrigators than for non-irrigators, implying that increased production efficiency due to irrigation management and use lead to higher income inequality.

Haileslassie et al. (2008) provided an overview of the range of key livelihoods and production systems in the Blue Nile Basin. Their report highlighted the relative dependence on, and vulnerability to water resources and water-related ecosystem services in the catchments. It also elucidated current water and land-related policies and institutions. Their major findings were that the livelihood base of the community, and land and water resources in the Blue Nile Basin are threatened. Interventions in upstream areas that aimed at improving the livelihoods of the local community will have an impact on the downstream region. Bringing a win-win scenario by up-scaling promising land and introducing improved water management technologies needs appropriate policy and institutional support. They recommend in-depth studies that can, ultimately, lead to a pragmatic policy suggestion.

Haile (2008) explored the impact of water harvesting irrigation development through pond, deep well and shallow well methods on poverty and livelihood in three districts, in Northern Ethiopia. His results indicated that households' access to deep well or shallow well irrigation has a significant impact on poverty reduction, through increasing household incomes, consumption and overall family employment. He recommended that policy-makers combine policy and regulatory actions, to increase the groundwater recharge and promote drip irrigation for improving water use efficiency of farmers.

Abraham (2010) evaluated the effects of irrigation development on poverty and income distribution in Banja *Wereda* (administrative district), Ethiopia. His results indicated that irrigation was a significant determinant of total income of rural households. He recommended that irrigation investment in rural areas appears to be an investment that can lead to both growth and equity.

Simeon (2010) evaluated the economic impact of the Prosperity through Innovation Irrigation Project, in Zambia. He had applied the Heckman two-stage procedure to account for the non-random assignment of programme participants. He found out that age of the household head, agricultural knowledge and the presence of friends or neighbours who already used micro-irrigation equipment were significant factors affecting voucher redemption. Moreover, his analysis showed that the adoption of a treadle pump had a positive impact on household assets.

Getaneh (2011) examined the impact of selected small-scale irrigation schemes on crops grown, total income and the likelihood of poverty at household level in Fogera District, Ethiopia. His results indicated that access to irrigation significantly reduced the odds that a household would be in the lowest quartile of household income, the key poverty threshold used in his study.

Dereje et al (2011) analyzed the poverty reduction impacts of Indris Irrigation Development Project, using the Heckman two-stage models in Ambo District, Western Ethiopia. Their results indicate that the incidence, depth, and severity of poverty are significantly lower among farm households with access to irrigation. They found out that farm size, livestock holding size, land productivity, and family size, significantly influence the level of household consumption expenditure, while access to irrigation was determined by asset, access to roads, age of the household, land fertility, and land productivity. This study employed qualitative and quantitative data to analyze innovative approaches used in irrigation water management and use in alleviating poverty. It also analyzed the impact of irrigation on poverty reduction.

2.3 Irrigation-Poverty Nexus

Some literature upholds that irrigation agriculture causes water logging, which creates conditions conducive to the multiplication of disease-causing agents such as malaria and schistosomiasis (Getaneh 2011; Haile 2008; Munawar 2004; Alam and Elias 2007; and Abraham 2010). Other environmental problems associated with irrigation are land degradation and salinity. On the other hand, other literature shows that irrigation is a major driving factor in the increase in rural household income, through agricultural growth. These studies strongly suggest that irrigation expansion is the main policy intervention, to alleviate rural poverty. Lipton et al. (2004) outlines four main inter-related mechanisms to reduce poverty:

- (a) Irrigation increases agricultural production and income, for households with access to irrigation. These outcomes are observed despite the price decrease that can occur as supply increases (other factors held constant). The price decrease can allow poorer households to more easily meet their basic needs. Household-level economic welfare is improved for the poor;

- (b) Irrigation protects farmers from the risk of crop loss associated with erratic, unreliable or insufficient rainfall;
- (c) Irrigation enhances the use of yield-enhancing farm inputs. The use of such farm inputs improves agricultural production and income;
- (d) Irrigation creates additional employment. Households and/or labourers are engaged in irrigation farming, which helps to increase productivity of labour during dry periods. Productivity of labour refers to output produced divided by labour employed.

Water is a valuable input for agriculture. Irrigation water appears to provide many pathways for poverty alleviation. The access to consistent irrigation water can enable farmers to adopt irrigation technologies. Irrigation facilitates intensity of cultivation, which leads to an increase in agricultural productivity and greater returns from farming. The expansion of irrigation opens up new employment opportunities in the household that increase the productivity of labour and land. This improves farm income, livelihoods, and the quality of life in rural areas (Hussain and Hanjra 2004). This study describes the impact of irrigation for poverty reduction and reducing income inequalities among different groups of households in Gerado Irrigation Scheme.

3. Research Design and Methodology of the Study

3.1 Description of the Study Area

3.1.1 Location and Geographical Setting

The study was conducted in South Wollo, situated in the northeastern highlands of Ethiopia. South Wollo, which is one of the 11 administrative zones of Amhara National Regional State (ANRS), is located between $10^{\circ}10'N$ and $11^{\circ}41'N$, and $38^{\circ}28'E$ and $40^{\circ}5'E$. The zone is divided into 24 *weredas* and 20 rural districts. Gerado Irrigation Scheme was selected for this study (Figure 1). The scheme is located in Dessie Zuria District, which is one of the 20 rural districts of South Wollo. Gerado Irrigation Scheme was selected based on accessibility for data collection, prevalence of irrigation water use for agriculture and accessibility for markets. It has been used by Endod ber and Bilen Kebele administrations (KAs).

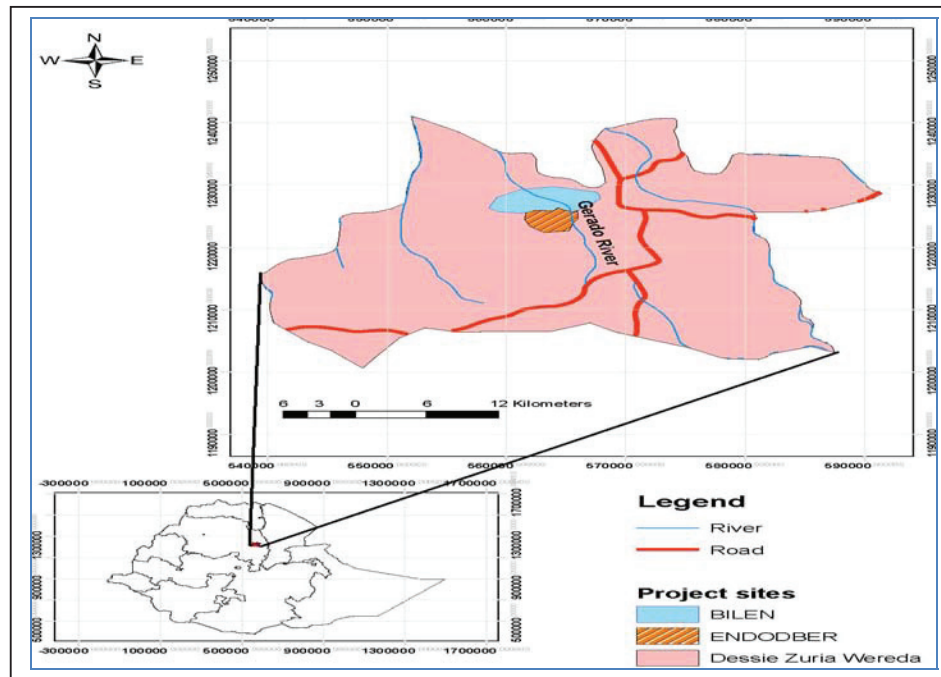


Figure 1. Map Showing Administrative Regions of Ethiopia and Study Areas

(Computed from data on Ethio-GIS)

3.2 Population

According to the Central Statistical Agency's population census data, about 61 per cent of Dessie Zuria (308,723) comprised of rural dwellers (CSA 2008). More than half of the people in the district were female.

3.3 Altitude, Topography and Climate

The study areas vary markedly in altitude, ranging from 1,700 to 3,807 meters above sea level masl) for Dessie Zuria (South Wollo DOA 1998). This range in elevation, along with the average annual temperature, forms the basis for classifying the district into various agro-ecological zones: high *Wurch* (>3,700 masl and < 7°C), *Wurch* (3,200-3,700 masl and 7-10°C), *Dega* (2,300-3,200 masl and 10-16°C), *Weyna Dega* (1,500-2,300 masl and >15-25°C) and *Kolla* (500-1,500 masl and 25-32°C) (South Wollo DOA 1998). The distribution of land area for Dessie Zuria, by agro-ecological zones comprises *Wurch* (6.68 per cent), *Dega* (73.74 per cent) and *Weina Dega* (19.5 per cent) (South Wollo DOA 1998). The topography is rugged and broken.

The study area is a moist, sub-humid area, which encounters a high mean annual moisture deficit. However, it has encountered recurrent droughts since 1953. Among the major droughts, the 1974 and 1984 droughts resulted not only in scarcity of food production but also in the death of a large number of people as well as animals (Hassen 2000). The mean annual maximum and minimum temperature for Kombolcha in the year 2000 was 26°C and 13°C, respectively. The mean annual rainfall and relative humidity was 1,139 millimetres and 55 per cent, respectively. The average annual temperature was 18.5°C for Dessie. The mean daily heaviest rainfall per year in millimeters, from 1969 to 2010, was 53 millimetres with a standard deviation of 13 for Dessie, while it was 51 millimetres with a standard deviation of 12 for Kombolcha. The minimum and maximum rainfall for both Dessie and Kombolcha was 30 millimetres and 83 millimetres, respectively. The result showed that there was a wide variability of rainfall, which depicted the impact of climate change on the production of crops and livestock rearing. This calls for adaptation in climate change by adopting irrigation.

3.4 Sample Size and Sampling Procedure

The study employed both qualitative and quantitative data for analysis. The sample size was also varied based on these sources of data. The study had used qualitative data from focus group discussions, informant interviews and participant observation. A multistage stratified random sampling procedure, with rural households as the sampling unit, was employed to analyze the impact of irrigation on poverty reduction, using quantitative data. The sampling process involved the selection of an irrigation scheme, KAs and sample farmers. In the first stage, Gerado Irrigation Scheme was purposely selected based on accessibility for data collection, prevalence of irrigation practice and proximity to the market. In the second stage, two KAs, Bilen and Endod Ber, were selected. The KAs are almost similar in topography, crop mix, use of technology, and proximity to an urban centre, and are the main users of the irrigation scheme.

In the last stage, the appropriate sample size for the study consisted of 150 farmers. These were randomly and proportionately selected, from irrigators (114) and non-irrigators (36). This task was performed by obtaining the list of irrigation users and non-users from development agent offices. After stratifying the households into irrigators and non-irrigators in each KA, sample farmers were randomly selected. This indicated that the proportion of sample farm households was 8 per cent of 1,228 irrigators and 655 non-irrigators in the scheme. The sample farmers were selected using probability proportional to sample size sampling technique (Table 1). Irrigators use irrigation from the scheme and other water harvesting technologies such as motor pumps and streams.

Table 1. Distribution of sample farm household heads by Kebele Administration

Statistics	Type of farmers	Sex	Name of Kebele Administration		
			Bilen	Endod Ber	Total
Population	Irrigators	male	578	486	1,064
		female	201	169	370
		total	779	655	1,434
	Non-irrigators	male	262	0	262
		female	187	0	187
		total	449	0	449
		total	1,228	655	1,883
	Irrigators	male	46	40	86
		female	16	12	28
Sample size	Non-irrigators	male	21	0	21
		female	15	0	15
	Total	male	67	40	107
		female	31	12	43
		total	98	52	150
	Male %		8.0	8.2	8.1
	Female %		8.0	7.1	7.7
	Total %		9	7.9	8.0

SOURCE: Development Agent Office (personal communication).

3.5 Sources and Methods of Data Collection

The fieldwork was conducted for eight months, from December 2011 to June 2012. Data collection methods consisted of informant interviews, focus group discussions, review of documents, and participant observation, to gather qualitative information at field and office level. Discussions were used as the main data gathering technique for qualitative information. This method allows a free exchange of information between the researcher and the participants. Moreover, a semi-structured interview was undertaken. The interview is a strategy for getting people to talk about what they know (Sarah 2002). It was developed to collect data necessary to analyze the different dimensions of poverty and determinants of the impact of irrigation on poverty alleviation. The questionnaire was pre-tested and revised accordingly, to evaluate enumerators and validate the content and method. Enumerators embarked on collection of data using the survey questionnaire, closely supervised by the researcher. Two development agents in the two KAs had provided support for data collection. In addition to primary data, secondary data was collected from different sources and levels, regarding the method and policy on irrigation development to alleviate poverty, such as published and unpublished documents, as well as from the government and non-governmental organizations (NGOs).

3.6 Methods of Data Analysis

Descriptive statistics; cost of basic needs, for setting poverty line; poverty indices (FGT model), for determining the dimensions of poverty; Gini coefficient, for computing inequality in income, expenditure and land distribution; and Heckman selection model, for assessing factors affecting impact of irrigation on poverty were all employed. The commonly applied poverty indices in the FGT model are head count ratio, poverty gap index and poverty severity index (Foster et al. 1984; MoFED 2008). The mathematical expression of the FGT model is:

$$P_{\alpha} = \frac{1}{n} \sum_{i=1}^q \left(\frac{Z - y_i}{Z} \right)^{\alpha} \quad (1)$$

where, P_{α} = poverty measure; Z = poverty line; y_i = expenditure; n = sample population number; q = the number of poor persons; and $Z - y_i$ = poverty gap. If $y_i < Z$, the household will be counted as poor whereas when $y_i > Z$, the household will be counted as non-poor. α = measure of sensitivity of the index to poverty or it is the poverty aversion parameter or the weight attached to the severity of the poor.

The measures are defined for $\alpha \geq 0$, the commonly used values of α are 0, 1, and 2. When α equals to 0 (all poor are given equal weight), equation (1) is reduced to the head count ratio, which measures the incidence of poverty or the percentage of people falling below the poverty line. The advantage of the head count measure is that the overall progress in reducing poverty can be assessed right away. Nevertheless, it is insensitive to the depth or severity of poverty and hence, not good to assess the impact of a policy measure. The latter is captured by the poverty-gap index. When α is equal to 1, we obtain P_1 or the poverty gap index, which estimates the average distance separating the poor from the poverty line or the average level of deprivation among the poor. The poverty gap could be understood as the amount of income transfer needed to close the gap. P_1 is sensitive to the depth of poverty but not to its severity. Setting α equal to 2, gives the severity of poverty or squared poverty gap index. This poverty index gives greater emphasis to the poorest of the poor, by squaring the transfers needed, as it is more sensitive to redistribution among the poor. It depicts the severity of poverty by assigning each individual a weight equal to his/her distance from the poverty line. Hence, P_2 takes into account not only the distance separating the poor from the poverty line but also the inequality among the poor. In developing the poverty line, the study identified the poorest 50 per cent of the population as the reference group.

An empirical model widely used to overcome such problems is the selectivity model suggested by Heckman (1979). According to Heckman's model, there are two equations of interest that should be modeled. These are the selection (participation) equation, and the response (outcome) equation. In the selection equation, the probability of participation in a

project is modeled conditional on some relevant observable variables, using a maximum likelihood Probit regression as follows:

$$Z_i = \sigma + \delta X_i + e_i \quad (2)$$

where Z is a latent variable, representing a household's likelihood of participation in a project, and X is the vector of individual, household and village characteristics that affect the probability of participation in a project. The Heckman two-step technique first estimates equation (2) and drives maximum likelihood estimates from the coefficients of the selection equation. Using these estimates, a variable known as the Mills ratio is constructed:

$$\lambda_i = \frac{\phi(\rho + \delta X_i)}{\psi(\rho + \delta X_i)} \quad (3)$$

where ϕ is the density function of a standard normal variable, Ψ is the cumulative distribution function of a standard normal distribution and λ_i is the Mills ratio term. The second stage involves adding the Mills ratio to the response equation and estimating the equation using two stages least square (2SLS) as follows:

$$Y_i = \beta_0 + \beta_{1i} X_i + \beta_{2i} Z_i + \beta_{3i} \lambda_i + e_i \quad (4)$$

where $E(e_i)=0$, Y_i is total household consumption expenditure per adult equivalent, X_i is a vector of individual, household and village characteristics and Z_i indicates whether a household is an irrigation beneficiary or non-beneficiary. The problem is that there may be a systematic, unobserved process that governs both participation of farm households in the small-scale irrigation project and the per capita consumption expenditure.

3.7 Hypotheses and Definitions of Variables for Determinants of Poverty

In this study, the variables were selected and hypothesized based on relevant literature, objectives of the study, farmers' production practices, researcher's local knowledge, and situations in the study areas.

(1) Dependent variables of Heckman selection model

The dependent variable of the Probit model takes a dichotomous variable, depending on farmers' decision whether to use or not to use the irrigation technologies. However, the selection model has a continuous value, which should be the total household consumption expenditure per adult equivalent.

(2) Definition of independent variables used in the Heckman selection model

Literature on adoption provides a long list of factors that influence the adoption of irrigation technologies. Generally, farmers' decision to use

improved agricultural technologies, such as irrigation, and the intensity of use in a given period of time, were hypothesized to be influenced by a combined effect of various factors such as individual and household characteristics, socioeconomic, institutional, and physical environments in which farmers operate. The explanatory variables included in the empirical models were selected based on the theory of farm level investment (Feder et al. 1985; Feder et al. 1992; Clay et al. 1998; Berhanu and Swinton 2003). In the course of identifying factors that influence farmers' decision to use improved agricultural technologies, the main task was to assess how a factor influences the farmer's decision and by how much (Table 2). The following explanatory variables were considered in the Heckman selection models.

Table 2. Definitions and measurements of variables used in the Heckman selection model

Definition of variables	Nature and units of measurement of variables	Expected sign
Dependent variables		
Access for irrigation	Dummy (Yes/no)	
Consumption per capita	Continuous (Kilogramme)	
Independent variables		
Distance to nearest market	Walking minutes	-
Age of the household head	Years	+/-
Education of the household head	Dummy (literate/illiterate)	+
Household size in adult equivalent	Number	-
Labour force in man equivalent	Number	+
Farm size	Total cultivated area in ha	+
Livestock owned	TLU	+
Sex of the household head	Male/female	+
Oxen ownership	Number	+
Irrigated farm size	Area in hectares (ha)	+
Household asset	Birr	+
Radio ownership	Dummy (Yes/no)	+
Access to off/non-farm income	Dummy (Yes/no)	+/-
Access to extension services	Dummy (Yes/no)	+
Access to credit services	Dummy (Yes/no)	+
Agricultural technology adoption	Dummy (Yes/no)	+

SOURCE: Feder et al. 1985; Feder et al. 1992; Clay et al. 1998; Gebremedhin and Swinton 2003

3.8 Estimation Procedure of the Empirical Model

Before running the model, the explanatory variables were checked for problems of multicollinearity and heteroscedasticity. According to Gujarati (1995), the problem of multicollinearity for continuous explanatory variables was investigated using Variance Inflation Factor (VIF), where

each explanatory variable was regressed on all the other explanatory variables. The larger the value of VIF is, the more serious the multicollinearity or collinear is the variable (X_j). As a rule of thumb, if the VIF of a variable exceeds 10 and R^2 exceeds 0.90, the variable is said to be highly collinear. In this study, the values of VIF for most of the explanatory variables included were less than seven, and it was concluded that there was no serious problem of multicollinearity (Appendix 1).

Moreover, to check the degree of association among explanatory variables, pair-wise correlation coefficients were computed. A correlation coefficient is a measure of association, where a value of 0.75 or above indicates a stronger relationship between explanatory variables (Healy 1984). In this study, pair-wise correlation coefficient was checked and almost all the values were found to be less than 0.75, for almost all variables, hence no signals of multicollinearity problems between explanatory variables (Appendix 2). However, the VIF and correlation coefficient for age and age square as well as household size and labour force available indicate the presence of multicollinearity. In this case, the economic significance of the variables matters more than the statistical significance. Heteroscedasticity problem were checked using Breusch-Pagan/Cook-Weisberg test. There was no heteroscedasticity problem. Therefore, dependent variables were regressed against explanatory variables using Heckman selection model.

4. Critical and Analytical Interpretation and Analysis of Data

4.1 Gerado Irrigation Scheme

Farmers have practiced irrigation on Gerado Irrigation Scheme for several years. In 1996, the regional government funded the development of the scheme. Commission for Sustainable Agriculture and Environmental Rehabilitation in Amhara Region (COSAERAR) was established for the diversion of the scheme. The objective of this development project was to irrigate 80 hectares, for 400 farmers. However, it was observed that the scheme was used by more than 1,200 farmers, to irrigate 250 hectares. The main beneficiaries of the scheme are farmers in Bilen and Endod ber KAs. This study tried to explore the innovative approaches used in managing and using irrigation for poverty alleviation in the study area.

4.2 Small-Scale Household Irrigation

Since 2005, the household level small-scale irrigation development programme has been the biggest development programme designed to address food insecurity, a key problem for the rural poor, in the most drought affected and densely populated areas. It developed a unique intervention — geomembrane, river diversion, family drip irrigation, motor and pedal pump irrigation — which was believed to be the best solution to fight drought through maximum utilization of available resources, namely labour, water and land. The goal of the programme was to achieve a breakthrough change by producing surplus food and creating a sustainable

environment for agriculture. The programme has attracted many stakeholders, including policy-makers, senior experts, donor agencies, and public sector agencies, who participated with good intentions and high expectations. During policy formulation, intensive studies that covered a wide range of issues were carried out by various experts, including senior development planners. Project planning was based on these studies and professional assumptions. The programme enjoyed strong policy support, attracted resources and had political backing. The state machinery, such as the district administration and KAs, were prepared to provide full support by mobilizing and convincing the community to accept and participate in the programme. Throughout the processes, the small-scale household level irrigation strategy dominates the policy. This trend was not without an impact on existing intervention strategies:

- Previously, lack of continuous interaction affected implementation capacities of farmers;
- The new intervention created additional irrigation innovation alternatives;
- Previous top-down approaches excluded the role of key actors;
- Small-scale household irrigation allows farmers to maximize benefits and utilize opportunities.

In the study area, many innovations are influenced by policy. The government is one of the key sources of information and knowledge for specific interventions (pumps and new seed varieties), it is the key actor in rural infrastructure development, is highly involved in credit provision, and plays a key role in mass mobilization for public works. This indicates that government policies can be central to encouraging or restricting innovation processes. Hence, the key question with regard to agricultural innovation becomes how to transform government structures into innovation stimulating actors. In the study area, agricultural policies, including irrigation programmes, are influenced by many government actors such as the political administration, media, farmers' organizations, and extension and credit systems. NGOs operate in limited areas and have limited influence. Therefore, the role of the state in overall development processes is central. The innovation system recognizes the central role of the state in innovation transformation, in weak market economies. Nevertheless, practical experiences are limited as to how to influence the government system towards an innovation encouraging institution.

The Gerado Irrigation Scheme case study indicates that even with positive attitudes towards reaching the poor, existing innovation interventions are difficult for the poor to adopt due to lack of investment capabilities such as labour, land and other resources. Hence, in the context of the study area, where the majority of households are poor, developing innovation capacity has strong linkages with household level asset endowments and its utilization.

4.3 Benefits of Irrigation for Poverty Alleviation

Irrigation provides water for crop and livestock production. The results of the study showed that irrigation was beneficial in terms of improving consumption habits, education and health of the family. The majority of irrigation users (67.5 per cent) stated that irrigation had benefited them in improving production of crops and livestock, which could ultimately improve consumption and the cash requirement of the household. The major benefits accrued to irrigation are summarized in Table 3. Respondents indicated that irrigation had benefited them in educating their children (14.9 per cent), improving health (11.4 per cent), providing livestock feed in dry seasons (2.6 per cent), constructing houses in town (0.9 per cent), and saving money in the bank (1.8 per cent).

Table 3. Major benefits (perceived) of irrigation for sample farm households

Benefits	Frequency	Per cent
Improved production for consumption	77	67.5
Improved education	17	14.9
Improved health	13	11.4
Improved livestock feed	3	2.6
Nutritious food	1	0.9
Built house in town	1	0.9
Save money in banks	2	1.8

SOURCE: Own survey, 2012

4.4 Creativity and Maximizing of Benefits from Irrigation

Respondents stated that some farmers had used certain methodologies to maximize benefits and create their own techniques for using and managing irrigation. These are summarized in Table 4. The majority of irrigation users (35.1 per cent) maximized benefits by shifting to production of horticultural crops. In addition to this, respondents indicated using various methodologies to maximize benefits, such as production of forage (3.5 per cent), increasing frequency of planting (9.6 per cent), use of motor pumps (1.8 per cent), and learning from others (6.1 per cent). However, about 43.9 per cent of irrigation users practiced still traditional methods of irrigation. This group of farmers grew cereals for subsistence purposes and did not produce surplus for the market.

Table 4. Creativity and maximizing of benefits from irrigation for sample farm households

Method of maximizing benefits	Frequency	Per cent
Shifting to horticultural crops	40	35.1
Production of forage	4	3.5
Increasing the frequency of planting	11	9.6
Using motor pumps	2	1.8
Learning from others	7	6.1
Has not maximized benefits	50	43.9
Total	114	100.0

SOURCE: Own survey, 2012

4.5 Irrigation Opportunities for Poverty Alleviation

Irrigation has the potential to provide water in dry seasons (43 per cent). Other opportunities include growing of high value crops (13.2 per cent), availability of feed in dry season (14 per cent), utilization of excess labour (17.5 per cent), and markets (12.3 per cent) as indicated in Table 5. There are great opportunities to diversify crops in irrigation canals, by producing high value crops.

Table 5. Opportunities of irrigation for poverty alleviation for sample farm households

Opportunity	Frequency	Per cent
Growing of high value crops	15	13.2
Availability of water in dry season	49	43.0
Availability of feed for livestock in dry season	16	14.0
Utilization of excess human labour	20	17.5
Utilization of markets	14	12.3
Total	114	100.0

SOURCE: Own survey, 2012

4.6 Challenges of Gerado Irrigation Scheme

Irrigation in the study area, regardless of its opportunities, has been confronted with various problems. Most irrigation users operate at subsistence and traditional level. They mostly practised minimal utilization of complementary inputs such as improved seeds, organic and inorganic fertilizers, and chemicals. Lack of marketing experience, required to penetrate outlets with very high trade requirements in terms of quality, packaging and other standards, is yet another problem. This is linked to low general management skills and other specific skills required for effective

production and marketing of irrigated crops. Respondents were asked about the major challenges encountered in the irrigation scheme. They reported that water shortage (43.9 per cent), fluctuation of prices (5.3 per cent), floods (5 per cent), pest infestation (9.6 per cent), frost (3.5 per cent), high price of inputs (5.3 per cent), water use conflict (5.3 per cent), lack of training (5.3 per cent), and participation (1.8 per cent) were major challenges encountered in the canal (Table 6).

Table 6. Challenges Encountered in Gerado Irrigation Scheme

Challenge	Frequency	Per cent
Water shortage	50	43.9
Pest infestation	11	9.6
Frost	4	3.5
High price of inputs	6	5.3
Lack of training	6	5.3
Lack of participation	2	1.8
Fluctuation of vegetable price	6	5.3
Water use conflict	6	5.3
Flood (overflow from the river)	8	7.0
Total	114	100.0

SOURCE: Own survey, 2012

Consequently, they opted to grow crops and vegetables, such as carrots, which are resistant to moisture shortages, stress, and have a high tolerance to diseases. An informal source for providing resolutions for water use conflict is an institution known as Yewuha Abat (father of water). The institution is organized in each irrigation site by the *wereda* office of agriculture and office of KA. The major duties of the institution include developing norms and procedures that would act as a by-law, designing/planning programmes for watering of irrigable land, collecting money from by-law violators, coordinating the users in undertaking repair and maintenance of the scheme, and acting as a transition for irrigation users' associations.

4.7 Profile of Consumption Poverty

Measures of consumption poverty are estimated and discussed in this subsection. The study followed the FGT model (1984) P α -measures of additively decomposable poverty measures to explain consumption poverty in Gerado Irrigation Scheme. Poverty indices for food and aggregate (total) were calculated based on three alternative poverty lines, namely extreme, absolute and moderate poverty. The food poverty line estimated for extreme, absolute and moderate poor were Ethiopian *birr* (Ethiopian currency) 1,500, 1,956 and 2,365, respectively (see Table 7).

Table 7. Alternative poverty lines in Gerado Irrigation Scheme

Alternative poverty lines	Food poverty line per adult equivalent per annum (<i>birr</i> [*])	Kcal per adult equivalent /day	Total poverty line per adult equivalent per annum (<i>birr</i>)
Extreme poverty line	1,500	1,650	1,967
Absolute poverty line	1,956	2,200	2,566
Moderate poverty line	2,365	2,750	3,102

SOURCE: Own survey, 2012

Note: * 1 Ethiopian *birr* = 0.0568 US dollar, as of July 2012

The total poverty lines were estimated by dividing the food poverty line by the percentage share of food in the household expenditure (76.2 per cent). The estimated poverty lines in this study are comparable with previous studies in the country (MoFED 2012).

The resulting food poverty estimates for non-irrigators and irrigators are summarized in Table 8.

Table 8. Food poverty profiles

Poverty indices	Non-irrigators		Irrigators		Total		t-value
	Index	SE	Index	SE	Index	SE	
Indices based on food poverty line (extreme poverty)							
P0	0.36	0.08	0.254	0.04	0.28	0.0368	2.7***
P1	0.175	0.045	0.102	0.0199	0.119	0.0188	2.9***
P2	0.104	0.0307	0.0553	0.0134	0.067	0.0127	2.8***
Indices based on food poverty line (absolute poverty)							
P0	0.472	0.084	0.4298	0.0465	0.44	0.041	1.1
P1	0.236	0.05	0.1595	0.023	0.178	0.0215	2.8***
P2	0.147	0.0374	0.086	0.0165	0.101	0.0155	2.9***
Indices based on food poverty line (moderate poverty)							
P0	0.583	0.0824	0.5614	0.0466	0.567	0.0406	0.6
P1	0.285	0.0533	0.2196	0.025	0.235	0.02	2.3***
P2	0.1827	0.0415	0.119	0.0185	0.1344	0.0174	2.8***

SOURCE: Model output and survey results (2012)

Note: P0= head count indices P1= poverty gap indices P2= severity of poverty indices

According to the survey, absolute head count index stood at about 47.2 per cent and 42.98 per cent, for non-irrigators and irrigators, respectively. Differences in the indices were statistically significant at 1 per cent probability level. This indicated that on average, 47 per cent of the population was under absolute food poverty, for non-irrigators. That is, they are unable to meet the minimum required calorie in-take, which is 2,200 kilocalories (kcal) per adult per day. The corresponding figure for irrigation users was lower. The normalized absolute poverty gap index, which is the average consumption shortfall needed to bring the entire population (those below the poverty line) up to the food poverty line, was 23.6 per cent and 15.95 per cent for non-irrigators and irrigators, respectively. The severity of absolute food poverty was 14.7 per cent and 8.6 per cent for non-irrigators and irrigators, respectively. Absolute poverty among irrigation users and non-users has a wide disparity. The result confirms that irrigation has an impact on reducing poverty. For comparison, extreme and moderate food poverty estimates for head count index were 0.36 and 0.58, respectively, for non-irrigators. Extreme and moderate food poverty estimates for head count index were 0.25 and 0.56, respectively, for irrigators. The resulting total poverty estimates for non-irrigators and irrigators are summarized in Table 9.

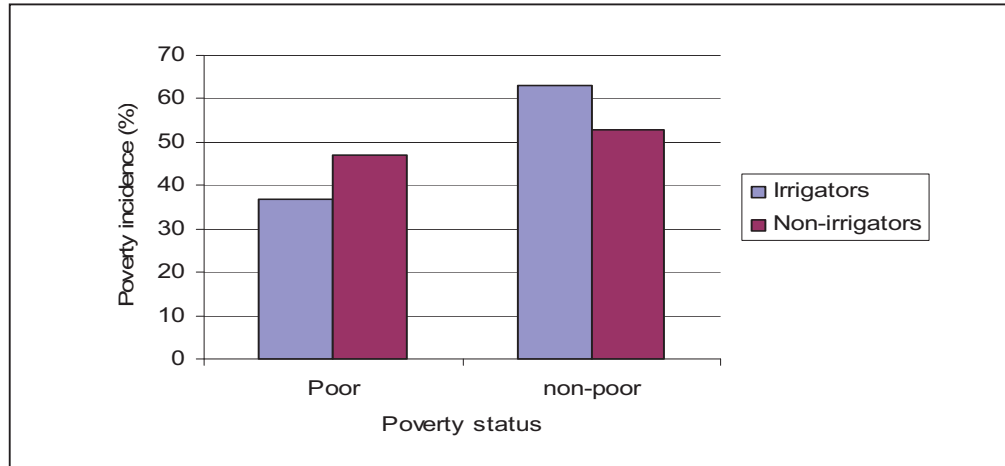
Table 9. Aggregate poverty profiles

Poverty indices	Non-irrigators		Irrigators		Total		t-value
	Index	SE	Index	SE	Index	SE	
Indices based on total poverty line (extreme poverty)							
P0	0.36	0.080	0.272	0.04	0.293	0.0373	2.2**
P1	0.156	0.042	0.0788	0.0157	0.0974	0.0158	2.9***
P2	0.087	0.0269	0.0343	0.0085	0.047	0.0094	2.9***
Indices based on total poverty line (absolute poverty)							
P0	0.472	0.084	0.368	0.045	0.393	0.040	2.7***
P1	0.212	0.048	0.137	0.020	0.155	0.0194	2.7***
P2	0.128	0.0339	0.066	0.012	0.081	0.0125	2.8***
Indices based on total poverty line (moderate poverty)							
P0	0.639	0.080	0.518	0.047	0.547	0.041	3.7***
P1	0.272	0.0502	0.193	0.023	0.212	0.0214	2.9***
P2	0.164	0.0384	0.0971	0.0149	0.1131	0.01479	2.8***

SOURCE: Model output and survey results (2012)

Note: P0= head count indices P1= poverty gap indices P2= severity of poverty indices *** and ** implies significant at 1 per cent and 5per cent probability level, respectively

According to the survey, absolute head count index stood at about 47.2 per cent and 36.8 per cent, for non-irrigators and irrigators, respectively (Figure 2).



The differences of the indices were statistically significant at 1 per cent probability level. This indicated that on average, 47 per cent of the non-irrigator population was under absolute total poverty. That is, they are unable to meet the minimum required calorie in-take. The normalized poverty gap index, which is the average consumption shortfall needed to bring the entire population (those below the poverty line) up to the total poverty line, was 21.2 per cent and 13.7 per cent, for non-irrigators and irrigators, respectively. The severity of poverty was 0.128 and 0.066, for non-irrigators and irrigators, respectively. Both absolute food and aggregate poverty among irrigation users and non-users indicated that irrigators had a lower poverty profile than their non-user counterparts. The result confirmed that irrigation could have an impact in alleviation of poverty. For comparison, extreme and moderate total poverty estimates for head count index were 0.36 and 0.639, respectively, for non-irrigators. Extreme and moderate food poverty estimates for head count index were 0.272 and 0.518, respectively, for irrigation users.

The proportion of people who are extremely poor is 36 per cent for non-irrigators and 27.2 per cent for irrigation users. The result that non-irrigation users experience more extreme aggregate poverty than their user counterparts is statistically significant at 5 per cent probability level. The depth and severity of aggregate absolute poverty are also more pronounced among non-irrigators, which is also statistically significant at 1 per cent probability level (Figure 3).

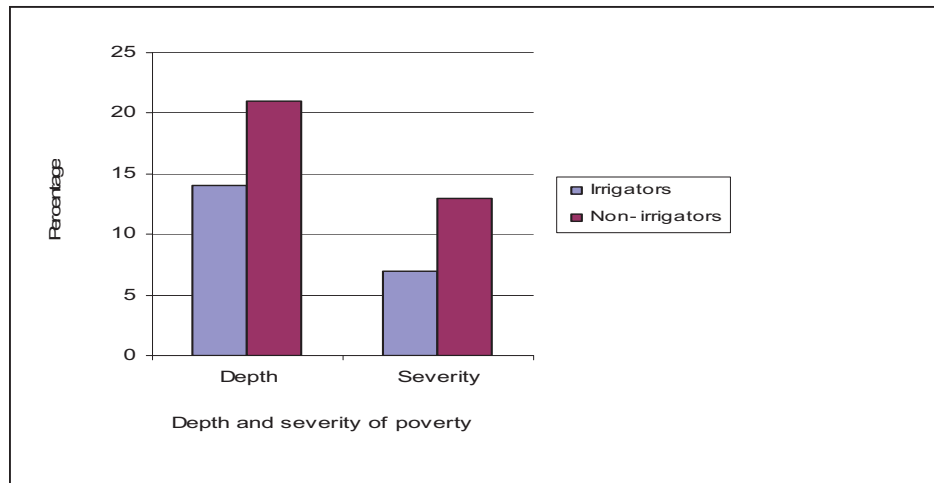


Figure 3. Depth and Severity of Aggregate Absolute Poverty among Irrigators and Non-Irrigators in Gerado

Source: Computed from Model Output and Survey Results, 2012.

For example, the total poverty gap index for absolute poverty (a measure of depth of poverty) is 13 per cent for irrigators and 21 per cent for non-irrigators. This implies that to lift the poor non-irrigators out of poverty, their current consumption level would have to increase by 21 per cent, while poor farmers from the irrigator group need only a 13 per cent increase from their current consumption level, to move above the poverty line. The squared poverty gap index (poverty severity) also indicates that inequality among the poor is higher for non-irrigators. In summary, significant welfare differences are observed between irrigators and non-irrigators; however, this difference could be due to observable and unobservable variables, other than access to irrigation.

4.8 Inequality in Per Capita Income, Expenditure and Land Distribution in Gerado Irrigation Scheme

To assess inequality in income, expenditure and land distribution among irrigation users and non-users, Gini Coefficient was estimated (Table 10).

Table 10. Gini coefficient estimate for income, expenditure and land distribution in Gerado

Name of variable	Irrigators		Non-irrigators		Total		t-value
	Estimate	SE	Estimate	SE	Estimate	SE	
Income per capita	0.380	0.028	0.343	0.053	0.398	0.026	-1.5
Expenditure per capita	0.277	0.037	0.297	0.016	0.285	0.016	-1.0
Cultivated land per capita	0.317	0.026	0.363	0.042	0.331	0.022	2.9***

SOURCE: Model output and survey results (2012).

Note: ***significant at 1per cent probability level

Gini Coefficient is the most popular measure of inequality. It estimates the degree of inequality in the distribution of income, expenditure and land. The value of Gini Coefficient ranges from 0 to 1, where 0 shows complete equality while the value 1 indicates complete inequality. The income Gini Coefficient was 0.398 for the whole sample. The value of income Gini Coefficient for irrigation users and non-users was 0.38 and 0.343, respectively. This indicated that there was higher income inequality among irrigation users than non-irrigators, implying that not only access to irrigation is important but also the method of using irrigation for alleviation of poverty. Some irrigation users did not maximize the benefits of irrigation due to shortage of labour and lack of awareness. Expenditure Gini Coefficient was lower than income Gini Coefficient. Expenditure Gini Coefficient with a value of 0.285 for all samples in the study areas indicated relatively less inequality in expenditure than in income. Relatively higher expenditure Gini Coefficient was estimated for non-irrigators. There was higher inequality in expenditure due to higher expenditure Gini Coefficient. The Gini Coefficient for land distribution was 0.331 for the whole sample. The Gini Coefficient for land was high for non-irrigators. The differences of the indices in land distribution were statistically significant at 1 per cent probability level.

4.9 Why are People Poor?

Additional information on the issue of why people are poor was obtained by decomposing poverty profiles of households with other socioeconomic variables. The study used variables such as sex of the household head, resource holding (mainly farm size, livestock and oxen holding), access to services (formal credit and extension services), and off-farm employment, and welfare variables such as off/non-farm income, total income and assets. As can be seen from Table 11, female-headed households had apparently lower poverty in terms of the incidence.

Table 11. Socioeconomic decomposition of poverty

Socioeconomic variables		Poverty indices		
	n	P ₀	P ₁	P ₂
Sex				
Female	43	0.419	0.190	0.114
Male	107	0.449	0.173	0.096
t-value		-1.1	0.9	1.4
Education				
Illiterate	74	0.486	0.221	0.133
Literate	76	0.395	0.136	0.069
t-value		45.0***	10.7***	10.4***
Access to extension				
No	82	0.488	0.213	0.121
Yes	68	0.382	0.135	0.076
t-value		12.9***	10.7***	9.5***
Access to credit				
No	138	0.420	0.180	0.105
Yes	12	0.667	0.152	0.057
t-value		2.9***	-0.9	2.2**
Farm size				
≥ mean	15	0.439	0.176	0.099
< mean	135	0.500	0.348	0.243
t-value		0.2	0.8	0.9
Livestock in TLU				
≥ mean	72	0.397	0.161	0.087
< mean	78	0.486	0.196	0.116
t-value		25.3***	7.1***	4.8***
Access to off/non-farm income				
No	32	0.395	0.138	0.075
Yes	118	0.461	0.196	0.112
t-value		-3.0***	-8.0***	-6.6***
Income				
≥ mean	54	0.315	0.118	0.066
< mean	96	0.510	0.211	0.120
t-value		-16.0***	-31.7***	-33.7***
Asset				
≥ mean	48	0.354	0.144	0.083
< mean	102	0.480	0.194	0.109
t-value		-6.4***	-5.2***	-3.1***
Oxen holding				
≥ mean	48	0.439	0.174	0.097
< mean	102	0.500	0.441	0.389
t-value		0.2	0.9	1.1

SOURCE: Model output and survey results (2012)

Note: ***, ** and * implies significant at 1 per cent, 5 per cent and 10 per cent probability level, respectively.

Poverty seems to be closely related to resource holding. Livestock holding is considered an important economic asset, not only because it is a major source of traction power and income but also because it is regarded as a source of social prestige. Households with a greater, or equal to mean, of livestock holding in TLU, displayed lower poverty measures than those having less than the mean. There is also a statistically significant difference in incidence, depth and severity of poverty, depending on whether households have access to education.

Similarly, households with farmland holdings greater than, or equal to the mean, depicted lower poverty levels than those having farmland holdings less than the mean. The differences in the indices were statistically significant, at 1 per cent probability level. There is also a difference in incidence, depth and severity of poverty, depending on whether households have access to formal credit. The results confirmed that poor households were the major beneficiaries of formal credit from microfinance institutions. Access to off-farm employment had also led to differences in poverty levels, which was statistically significant at 1 per cent probability level. The incidence, depth and severity of poverty were lower in households with access to extension services. Household farmland holdings greater than or equal to the mean, in welfare variables, depicted lower poverty levels than those having farmland holdings less than the mean. The survey results confirmed that access to, and control and use of resources had a significant impact in reducing poverty. The study further evaluated the relevant policy factors that affect access to irrigation and welfare, as shown in the following section.

4.10 Results of the Heckman Selection Model

4.10.1 Factors Explaining the Probability of Access to Irrigation: Probit Regression Results

In the first stage of the Heckman model, a Probit equation was estimated (Table 12).

Table 12. Factors affecting access to irrigation and welfare using Heckman selection model

Variables	Probit equation		Response equation		
	Coefficient	SE	Marginal effect	Coefficient	SE
Sex	0.464	0.349	0.095	114.815	337.118
Age	0.0203	0.012*	0.0046	27.272	11.00**
Age square	-0.001	0.0004**	-0.003	-0.111	0.0582*
Distance to market	-0.0741	0.0402*	-0.0169	-	-
Education	0.426	0.128**	0.0976	64.656	290.845
Labour available	0.506	0.277**	0.0115	452.401	212.696**
Household size	-0.1653	0.237	-0.0378	-886.336	203.190***
Farm size	0.945	0.446**	0.2277	85.268	332.336
Irrigated land	-	-	-	156.765	36.114***
Number of oxen	0.409	0.222*	0.0934	-	-
Livestock in TLU	0.2548	0.112**	0.056	55.6176	23.058**
Off/non-farm	0.303	0.370	0.0597	91.0480	249.853
Agri. technology	0.200	0.403	0.038	-517.913	401.652
Extension service	0.5967	0.418	0.119	722.732	275.326**
Credit service	1.272	0.757*	0.142	-418.060	407.032
Radio ownership	1.116	0.411***	0.234	-	-
Household asset	-	-	-	442.380	165.469***
Constant	-0.951	0.782	-	1746.49	1786.826
Mills ratio (lambda)				-310.86	125.35**
Wald chi2(14)					
Number of observation		150			

SOURCE: Model output and survey results (2012)

Note: ***, ** and * implies significant at 1 per cent, 5 per cent and 10 per cent probability level, respectively

Estimates of the Probit equation revealed that seven variables were statistically significant in explaining the farming household's likelihood of access to irrigation. Variables that increase the probability of access to irrigation were the education of the household head; labour available in the family; number of oxen; livestock holdings; access to credit services; radio ownership; total farm size; and age of the household head; However, the distance to market variable decreases the probability of access to irrigation. Men were more likely to have access to irrigation than women, but this was not statistically significant.

Age of the farming household head had a significant positive effect on access to irrigation, at 10 per cent probability level. This might be related to the fact that older farmers might have gained more knowledge. The result is consistent with the findings of Teklewold et al. (2006), Hailu (2008), and Dereje et al. (2011). However, age square had the expected negative relationship with access to irrigation, at 5 per cent probability level. Education level of the farming household head was hypothesized to affect access to irrigation technology positively, since it increases the capacity of farming households to acquire information and knowledge about improved technologies, and promote the decision to use it on his/her farm. In this study, in conformity with the hypothesis, education positively and significantly influenced the probability of access to irrigation, at 5 per cent probability level. The result is consistent with the findings of Doss and Morris (2001), and Abay and Assefa (2004). Labour force available in the household influenced the probability of access to irrigation positively, at 5 per cent probability level. The probable reason is that improved practices, such as irrigation, are labour intensive, hence the household with a relatively high labour force uses the technologies on their farm holdings more than those with a low labour force. This result is consistent with the findings of Hailu (2008). Livestock ownership in TLU and oxen ownership are considered as an asset that could be used either in the production process or in exchange for the purchase of inputs and food. Possession of a lot of livestock, including oxen, indicates greater wealth and capacity, and encourages investment in irrigation technologies. In this study, ownership of livestock and oxen had the expected positive and significant effect on the probability of access to irrigation, due to availability of cash to ease financial constraints, at 5 per cent and 10 per cent probability level, respectively. The result is consistent with the findings of Abay and Assefa (2004).

In conformity with the hypothesis, farm size influenced the probability of access to irrigation positively, at 5 per cent probability level. The result is consistent with the findings of Doss and Morris (2001). Farm size is an indicator of wealth, and perhaps, a proxy for social status and influence within a community. Radio is one of the major sources of information for improved agricultural technologies. Radio ownership had the expected positive and

significant effect, at 1 per cent probability level, on probability of access to irrigation due to access to information for improved technologies. The result is consistent with the findings of Teklewold et al. (2006).

Agricultural credit services are the main source of funds to implement improved irrigation technologies. If farmers have access to credit, they can purchase improved technologies. Access to credit had the expected positive and significant effect, at 10 per cent probability level, on probability of access to irrigation due to access to finance for inputs. The result is consistent with the findings of Abay and Assefa (2004) and Teklewold et al. (2006). According to the results of the Heckman model, farmers who received credit were about 14.2 per cent more likely to adopt irrigation technology than those who did not. In many cases, farmers need to use some of their own equity to finance at least part of their investments. In other case, assets such as land or the crop itself may be used as collateral for financing an improved technology. The result, therefore, suggested that the availability of credit was one of the most important determinants of smallholder farmers adopting irrigation technology.

The coefficient of the distance from farmer's home to the nearest market had the expected negative sign and significant effect on the probability of access to irrigation technologies. The negative sign indicated the importance of proximity to a regular market, leading to better access, lower transport costs, timely delivery of inputs, disposal of output, and better output price for farmers. The market is used to buy required inputs and sell surplus output. Thus, closer distance of a farmer's home to the market enables and facilitates marketing of inputs and outputs.

The marginal effect analysis showed that a unit increase in household available labour increases the likelihood of participation in the irrigation scheme by 1.12 per cent, keeping other determinants at their mean levels. However, the relationship between household size and the probability of access to irrigation is negatively correlated but insignificant. The relationship between the probability of access to irrigation and age is non-linear. A unit increase in age increases the probability of access to irrigation by about 0.4 per cent, but only up to a certain point, after which a further increase in the age of the household head decreases the probability of access to irrigation by 0.3 per cent. This could imply either that older farmers have a decreased probability of obtaining access to irrigation or that they may have relinquished the ownership of their irrigated farms to their younger descendants. The education and farm size are significant predictors of whether a farmer has access to irrigation. For example, as farm size increased by one hectare, the probability of a farmer using irrigation increased by 22.7 per cent.

4.10.2 Determinants of Consumption Expenditure: Does Access to Irrigation Matter?

Results from the second stage of the Heckman model, or the response equation, are also presented in Table 12. The model confirmed that irrigated land size, in hectares, significantly ($p < 0.01$) increased the level of total household consumption, per adult equivalent. This is confirmed by the statistical significance of the irrigated land and lambda variables. The result is consistent with the findings of Dereje et al. (2011). The other significant welfare determinants (household consumption expenditure per adult equivalent) were labour available, size of livestock owned, farm size, household assets, extension services, and age (proxy for farming experience). These variables contributed positively to household welfare. However, household size and age square was correlated negatively to welfare. The relationship between household size (in adult equivalent) and household total consumption expenditure (per adult equivalent) is negative, indicating that as the household size increases, the welfare of a family decreases. However, the relationship between household labour force (in man equivalent) and household total consumption expenditure (per adult equivalent) was positive. This may be due to the labour-intensive nature of the irrigation business. Household size, in adult equivalent, was found to significantly and negatively influence the intensity consumption expenditure, per adult equivalent, at 1 per cent probability level. This implies that an increase in adult equivalent negatively influences (through increases in household food requirement) the decision to consume more food. Consequently, increase in household size negatively influences the household food requirement, and the decision to consume more food.

Once a family has access to irrigation, increasing the workforce within a household is an increased liability because it enables agricultural intensification. The positive and significant influence of household assets on consumption expenditure of the household may be due to the fact that the income is used to improve the experience, as well as human and physical capital of the farming household, and serve as additional funding to satisfy the consumption requirement.

Visiting the development agent had the expected positive and significant effect, at 5 per cent probability level, on probability of adoption due to access to information for irrigation technologies. Agricultural extension services are the major source of information for improved agricultural technologies. One means by which farmers access information on improved technologies is by contacting the extension agent. The result is consistent with the findings of Teklewold et al. (2006). The relationship between age variables is non-linear as indicated by the statistical significance of its squared terms in the model.

The explanation for the inverted U-shaped relationship between the age of the household head and welfare is rather straightforward: old farm households would have fewer opportunities to make the best use of their resources, including irrigated farms. The presentation of the marginal effects of these variables is important because the magnitude of the marginal effects is indicative of the degree of importance, or policy relevance of the variables. Marginal effects of the variables are computed for those households with access to irrigation (N=114).

The marginal effects indicate the change in total household consumption expenditure resulting from a unit change in the explanatory variable for the irrigated household. Among those who have access to irrigation, a hectare increase in irrigated area would increase the total household consumption expenditure by Ethiopian *birr* 156. However, a unit increase in household size decreases total household consumption expenditure by Ethiopian *birr* 881. A hectare increase in available labour in the family would increase the total household consumption expenditure by Ethiopian *birr* 440. The implication is that an irrigated farm can support more people by creating conditions for intensification. Other significant policy relevant variables, in order of importance, are extension services, total household assets and number of livestock owned in TLU. A percentage increase in the household asset base improves household consumption expenditure by Ethiopian *birr* 440 ($p < 0.01$) for those with access to irrigation. A unit increase in livestock size in tropical livestock unit (TLU) improves a household's consumption expenditure by about Ethiopian *birr* 55. A unit increase in access to extension services increases total household consumption expenditure by Ethiopian *birr* 634, for those with access to irrigation.

5. Conclusions and Recommendations

5.1 Summary of Key Findings and Conclusion

The objective of this study was to describe and analyze existing and potential innovative approaches that are used by local communities, and to examine dimensions of poverty and determinants of the use of water resources for poverty alleviation in South Wollo. Gerado Irrigation Scheme was selected as a case study. Data were collected for the period December 2011 to June 2012, and analysis was carried out with the help of various descriptive and econometric techniques.

Socioeconomic and agricultural characteristics were identified for farming households in the scheme. It was found that the percentage of female households in the whole sample was 28.7 per cent. The average age of the household head was 47.6, 43 and 49 years, for the whole sample, comprising non-irrigators and irrigators, respectively. The average available labour force

in the family for the irrigation users and non-users was 3.9 and 3.09, respectively. Illiterate farming households represented 49.3 per cent of the sample household. The average farm size of irrigation users was higher than their non-user counterparts. In rainfed agriculture, wheat and teff area were the major cereal crops grown, with yields of 1,641 and 1,056 kilogrammes per hectare, respectively. Moreover, horse beans and chick peas were the major pulse crops grown, with a yield of 1,105 and 1,382 kilogrammes per hectare, respectively. The majority of farmers cultivated teff and wheat under rainfed agriculture.

Under irrigated agriculture, the bulk of the farming area was covered by wheat and maize, with yields of 1,294 and 2,031 kilogrammes per hectare, respectively. Moreover, major vegetables grown were carrots and potatoes, with yields of 9,198 and 11,818 kilogrammes per hectare, respectively. The number of farmers who cultivated maize was ranked first (34 per cent), followed by carrots at 24.7 per cent. The major livestock species owned by the household were cattle, goats, horses, mules, and donkeys. The average livestock holding in TLU was 3.45 and 1.75, for irrigators and non-irrigators, respectively. Irrigation was one of the techniques used to supplement feed for livestock, either through irrigation of pasture land or crop residues obtained from irrigation production.

The survey results showed that farmers' income was obtained from non-farm activities, remittances, productive safety net programme, and crop and livestock production activities. An average farming household's income from crops was Ethiopian *birr* 4,954 and 12,967, for non-irrigators and irrigators, respectively. Irrigation contributed 27.5 per cent of the total farm income for irrigation users. Irrigation had benefited households in improving consumption habits, education, health, increased feed for livestock, and saving money in the bank. Irrigation users had maximized benefits through shifting to horticultural crops, increasing frequency of planting and using motor pumps. Irrigation users stated that adoption of water harvesting technologies (46.5 per cent), horticultural crops (27.2 per cent), increasing the frequency of planting (14.9 per cent), training (2.6 per cent), and awareness creation (8.8 per cent) were important steps in alleviation of poverty. The major opportunities of irrigation in the canal were provision of water during the dry season, growing of high-value crops, availability of feed in dry seasons, and utilization of excess labour and markets. Farmers reported that water shortage (43.9 per cent), fluctuation of prices (5.3 per cent), floods (5 per cent), pest infestation (9.6 per cent), frost (3.5 per cent), high price of inputs (5.3 per cent), water use conflicts (5.3 per cent), lack of training (5.3 per cent), and lack of participation (1.8 per cent) were the major challenges encountered in the scheme.

Foster, Greer and Thorbecke (1984) model was applied, to explain consumption poverty in Gerado Irrigation Scheme. Poverty indices for food and aggregate (total) are calculated based on three alternative poverty lines, for extreme, absolute and moderate poverty in the study area. The food poverty lines estimated for extreme, absolute and moderate poor were Ethiopian *birr* 1,500, 1,956 and 2,365, respectively. Absolute head count index stood at about 47.2 per cent and 42.98 per cent, for non-irrigators and irrigators, respectively. The normalized absolute poverty gap index, which is the average consumption shortfall needed to bring the entire population (those below the poverty line) up to the food poverty line, was 23.6 per cent and 15.95 per cent, for non-irrigators and irrigators, respectively. The severity of poverty was 0.147 and 0.086, for non-irrigators and irrigators, respectively.

The proportion of people who are extremely poor is 36 per cent, for non-irrigators, and 27.2 per cent for irrigation users. The result that non-irrigation users experience more extreme poverty than their user counterparts is statistically significant, at 5 per cent probability level. The depth and severity of poverty are also more pronounced among non-irrigators, which are also statistically significant, at 1 per cent probability level. For example, the total poverty gap index for absolute poverty (a measure of depth of poverty) is 13 per cent for irrigators and 21 per cent for non-irrigators. This implies that to lift the poor non-irrigators out of poverty, their current consumption level would have to increase by 21 per cent, while poor farmers from the irrigator group only need a 13 per cent increase from their current consumption level, to move above the poverty line. Inequality in income, expenditure and land distribution, were estimated using Gini Coefficient. The result confirmed that income per capita inequality was higher than expenditure per capita. Moreover, inequality in income per capita was higher for irrigation users than their non-user counterparts. Decomposition of poverty indicated that low resource endowed households, including non-irrigators, were highly deprived.

The probability of access to irrigation was increased by the education of the household head; labour available in the family; number of oxen and livestock holdings; access to credit services; radio ownership; total farm size; and age of the household head. However, distance to market and age square variables decreased the probability of access to irrigation. Welfare (household consumption expenditure per adult equivalent) was positively determined by irrigated land; labour available; size of livestock holdings; farm size; household assets; extension services; and age (proxy for farming experience). However, household size and age square was correlated negatively to welfare.

5.2. Policy Recommendations

- Agricultural productivity and income was higher for irrigation users as compared to the non-users. Poverty profiles also indicated that farming households with small-scale irrigation were not as poor as households without irrigation. Access to irrigation, through small and large-scale irrigation, must be ensured to increase productivity, hence reduce and subsequently alleviate poverty in the region. This would help households to adapt to the increasing climate change being experienced in the country.
- People are poor due to shortage of resources or an inability to use resources. Therefore, farming households' asset formation, and provision of extension and credit services should be given priority. Such actions may, in turn, alleviate the current problem of food insecurity, and lead to economic development, in the long run.
- Water shortage was the major constraint cited in the scheme. Some innovative farmers had obtained better yields and increased income through groundwater rather than go through the long process of water distribution from the canal. Therefore, it is suggested that methods of irrigation should be diversified through ground and surface water systems.
- Household size and education of the household has a strong link to poverty. Large household size and illiteracy among the poor in the region were the main determinants of poverty. Population planning interventions, along with a holistic approach in improving the education level of people, are required to overcome the poverty problem.
- The analysis showed that farmers had obtained better income from irrigation water, therefore water-pricing mechanisms could be introduced for rational allocation of water. This would also encourage water markets to develop in the study area, in particular, and Ethiopia at large. Moreover, it would help to establish sustainability and efficiency of irrigation in the region, through developing sustained cost-recovery systems.
- The study suggests increasing awareness of farmers and farmer participation in management decision-making, to achieve higher efficiency in the conveyance of irrigation water, and ensuring sustainability of irrigation infrastructure. The study suggests co-opting farmer's in top-level decision-making, to enhance efficiency in irrigation practices and ensure sustainability of irrigation infrastructure.

- The results showed that the government was the main source of the innovation process in irrigation development and expansion. Such sources of innovation should incorporate the views and ideas of the remaining implementing actors.

Acknowledgments

While conducting the research and writing this report, I received encouragement and support from various individuals and institutions. I am deeply grateful to OSSREA, without whose permission and financial assistance, this paper would not have been possible. Furthermore, I would like to acknowledge the enumerators — Kelemework, Daniel, Habib, and Alifya — for administering the survey questionnaires to the level required. I am grateful to the farmers who spared their precious time to respond to the lengthy questionnaires and actively engage in discussions. Without their contribution, this report would not have been possible.

References

- Abraham, S. 2006. Evaluating the effects of irrigation on poverty and inequality in Banja Woreda, Amhara Region. MSc Thesis. Addis Ababa University, Ethiopia.
- Alam, Q. M and Elias, S. M. 2007. Impact of irrigation on income distribution across regions in Bangladesh. *Bulletin of the Institute of Tropical Agriculture, Kyushu University*, 30: 47-56.
- Asfaw, A. and Admassie, A. 2004. The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. *Agricultural Economics*, 30: 215–228.
- Awulachew, S. B., Yilma, A. D., Loulsegged, M. and Loiskandl, W. 2007. Water resources and irrigation development in Ethiopia. Working Paper 123. Colombo, Sri Lanka: International Water Management Institute (IWMI).
- Berhanu, G. and Swinton, S. M. 2003. Investment in soil conservation in Northern Ethiopia: The role of land tenure security and public programme. *Agricultural Economics*, 29: 69-84.
- Berhanu, G. and Pedon, D. 2002. Policies and institutions to enhance the impact of irrigation development in mixed crop–livestock system. In *Integrated water and land management research and capacity building priorities for Ethiopia*. Proceedings of MoWR/EARO/IWMI/ILRI International Workshop held at ILRI, Addis Ababa, Ethiopia, December 2-4, pp. 168–184.

- Bhattarai, M., Sakthivadivel, R. and Hussain, I. 2002. Irrigation impacts on income inequality and poverty alleviation: Policy issues and options for improved management of irrigation systems. Working Paper 39. Colombo, Sri Lanka: International Water Management Institute.
- Clay, D. C., Reardon, T. and Kangasniemi, J. 1998. Sustainable intensification in the highland tropics: Rwandan farmers' investment in land conservation and soil fertility. *Economic Development and Cultural Change*, 46: 351–378.
- Central Statistical Agency (CSA). 2008. The 2007 population and housing census of Ethiopia. Statistical Report on Population Size and Characteristics, 1 (1), Federal Democratic Republic of Ethiopia Central Statistical Agency, Addis Ababa, Ethiopia.
- David, R., Shillington, E. R. and Lochhead, C. 1994. A working definition of Statistics Canada Low Income Cut-offs (LICOs). Excerpt from *Canadian fact book on poverty*. Canada: The Canadian Council on Social Development.
- Dercon, S. and Krishnan, P. 1998. *Changes in poverty in rural Ethiopia, 1989-1995: Measurement, robustness tests and decomposition*: Centre for the Study of African Economies, Institute of Economics and Statistics, University of Oxford.
- Dereje, B., Regassa, N. Ayalneh, B. and Abonesh, T. 2011. Impact of small-scale irrigation on household poverty: Empirical evidence from the Ambo District in Ethiopia. *Irrigation and Drainage*, 60: 1–10.
- Doss, C. R. and Morris, M. L. 2001. How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. *Agricultural Economics*, 25: 27–39.
- Dupriez H, and De Leener. 2002. Land use and life: Ways of water, runoff, irrigation and drainage. In *Tropical handbook*. Netherlands: CTA and TERRES ET VTE.
- Edilengaw, W. 1997. Household income inequality and poverty during structural adjustment: The case of Ghana. MSc Thesis, Wageningen Agricultural University, The Netherlands.
- Food and Agriculture Organization (FAO). 2005. Irrigation in Africa in figures. AQUASTAT Survey –2005. Water Report 29. Rome: FAO.
- Feder, G. L., Just, R. E. and Zilberman, D. 1985. Adoption of agricultural innovation in developing countries: A survey. *Economic Development and Cultural Change*, 32 (2): 255–298.

- Feder, G., Lau, L. J., Lin, J. Y. and Luo, X. 1992. The determinants of farm investment and residential construction in post-reform China. *Economic Development and Cultural Change*, 41: 1–26.
- Foster, J., Greer, J. and Thorbecke, E. 1984. A class of decomposable poverty measures. *Econometrica*, 52 (3): 761-766.
- Gebremedhin, B. and D. Pedon. 2002. Policies and institutions to enhance the impact of irrigation development in mixed crop–livestock system. In *Integrated Water and Land Management Research and Capacity Building Priorities for Ethiopia*. Proceedings of MoWR/EARO/IWMI/ILRI International Workshop held at ILRI, Addis Ababa, Ethiopia, 2–4 December; 168–184.
- Gebremedhin, B. and S.M. Swinton. 2003. Investment in soil conservation in Northern Ethiopia: The role of land tenure security and public programme. *Agricultural Economics*, 29: 69-84.
- Getaneh, K. 2011. The impact of selected small-scale irrigation schemes on household income and the likelihood of poverty in the Lake Tana basin of Ethiopia. MSc Thesis, Cornell University.
- Government of Ethiopia (GoE). 2007. Climate Change National Adaptation Programme of Action (NAPA) of Ethiopia. Ministry of Water Resources and National Meteorological Agency, June 2007.
- Gujarati, N.D., 1995. Basic Econometrics. 3rd edition. NY: McGraw-Hill, Inc.
- Haile, T. 2008. Impact of irrigation development on poverty reduction in Northern Ethiopia. PhD. Dissertation, National University of Ireland.
- Haileslassie, A., Hagos, F., Mapedza, E., Sadoff, C., Awulachew, S. B., Gebreselassie, S. and Peden, D. 2008. Institutional settings and livelihood strategies in the Blue Nile Basin: Implications for upstream/downstream linkages. Working Paper 132. Colombo, Sri Lanka: International Water Management Institute.
- Hailu, B. 2008. Adoption of improved teff and wheat production technologies in crop and livestock mixed systems in Northern and Western Shewa zones of Ethiopia. PhD. dissertation, University of Pretoria.
- Hassen, B. 2000. Crop-livestock integration on smallholders' farms and their potential for improvement in South Wello, Ethiopia: A case study of Debresina and Tehulederie districts. MSc thesis, Alemaya University.
- _____. 2011. Analysis of agricultural technology adoption and production efficiency: The case of smallholder farmers in Northeastern Highlands of Ethiopia. PhD. dissertation, School of Graduate Studies, Haramaya University, Ethiopia.

- Heckman, J. 1979. Sample selection bias as a specification error. *Econometrica*, 47 (1): 153–162.
- Healy, F. J. 1984. Statistics: a tool for social research. CA: Wadsworth Publishing Company.
- Hussain, I. and Hanjra, M. A. 2004. Irrigation and poverty alleviation: Review of the empirical evidence. *Irrigation and Drainage*, 53: 1–15
- Lipton, M., Litchfield, J. and Figures, J. M. 2004. The effects of irrigation on poverty: A framework for analysis. *Water Policy Journal*, 5 (5-6): 413-427.
- McClelland, A. 2000. No child...: Child poverty in Australia. Summarized by Bette Moore in Child poverty: The facts. Brotherhood of St Laurence, Fitzroy, Vic. Retrieved July 2, 2011, from: <http://catalogue.nla.gov.au/Record/301758>.
- Ministry of Agriculture (MOA). 2005. Fogera Woreda Pilot Learning Site Diagnosis and Programme Design. In ILRI Fogera PLS planning workshop programme, October 1- 2; Woreta Town.
- Ministry of Finance and Economic Development (MoFED). 2006. Ethiopia: Building on progress. A plan for accelerated and sustained development to end poverty (2005/6 –2009/10). Addis Ababa, Ethiopia
- _____. 2008. Dynamics of growth and poverty in Ethiopia (1995/96-2004/05). Addis Ababa, Ethiopia.
- _____. 2012. Ethiopia's progress towards eradicating poverty: An interim report on poverty analysis study (2010/11). Addis Ababa, Ethiopia.
- Ministry of Water Resources (MoWR). 2001. Irrigation development strategy. Draft Report. Addis Ababa, Ethiopia.
- Munawar, H. 2004. Impact of small-scale irrigation schemes on poverty alleviation in marginal areas of Punjab, Pakistan. PhD dissertation. University of agriculture, Faisalabad.
- Panneerselvam, R. 2004. *Research methodology*. New Delhi: Prentice Hall .
- Ravallion, M. 1998. Poverty lines in theory and practice. Living standards measurement study. Working Paper 133. Washington, D.C: World Bank.
- RiPPLE. 2010. Small-scale irrigation in the Ethiopian highlands. What potential for poverty reduction and climate adaptation? Briefing Paper No. 3. Retrieved August 17, 2011, from www.rippleethiopia.org.
- Sarah, S. 2002. Methods and techniques of field research. WAU.
- Sen, A. 1981. *Poverty and famine: An essay on entitlement and deprivation*. Oxford: Oxford University Press.

- Simeon, W. D. 2010. Evaluation of the livelihood impacts of a micro-irrigation project in Zambia. MSC thesis, Ohio State University
- South Wollo Department of Agriculture (DOA), 1998. Land use/land cover systems, limitation and potential. Unpublished document, Dessie, Ethiopia.
- Tassew, W. 2004. The experiences of measuring and monitoring poverty in Ethiopia. A paper presented for the Inaugural Meeting of the Poverty Analysis and Data Initiative (PADI). Mombasa, Kenya.
- Teklewold, H., Legesse, D., Yami, A. and Dana, N. 2006. Determinants of adoption of poultry technology: A double-hurdle approach. *Livestock Research for Rural Development*. 18 (40). Retrieved November 30, 2008, from <http://www.cipav.org.co/lrrd/lrrd18/3/tek118040.htm>
- Widtose, J. A. 2001. Irrigation Practices. Updesh Purhohit for Agrobios. Jodhpur, India,.
- World Bank. 1990. World Development Report. NY: Oxford University Press.
- _____. 2000. World Development Report. Washington D.C: World Bank
- _____. 2006. Ethiopia: Managing water resources to maximize sustainable growth. A World Bank Water Resources Assistance Strategy for Ethiopia. Washington, D.C: World Bank.

Appendix 1. Variance Inflation Factors (VIF) of the Explanatory Variables

Variable	Code	Collinearity Statistics	
		VIF	Tolerance=1/VIF
Age of the head	agehhh	13.55	0.074
Age square	agesq	12.56	0.080
Labour force available	menumb	11.18	0.089
Household size	aenumb	10.85	0.092
Livestock ownership in TLU	tlu	4.51	0.222
Oxen ownership	oxen	4.41	0.227
Farm size	tcultland	2.96	0.338
Access to extension service	davisit	2.53	0.396
Radio ownership	radio	2.43	0.411
Number of plot	nplot	2.1	0.476
Irrigated land	irrigland	1.85	0.540
Sex of the head	sexhhh	1.62	0.616
Agricultural technology adoption	agritop	1.56	0.642
Education of the head	educhhh	1.51	0.662
Total household asset	thhasset	1.47	0.680
Off/non-farm income	offarmp	1.3	0.770
Distance to road	dishoroad	1.2	0.831
Credit participation	creditp	1.15	0.867

Appendix 2. Pair Wise Correlation Coefficient of Explanatory Variables for Heckman Selection Model

Variable	distmark	disroad	sexhhh	agehhh	educhhh	menumb	aenumb	tcultland	nplot	irrigland	oxen	tlu	offfarm	thhasset	agritop	radio	davisit	creditp	agesq
disthmtma-t	1																		
dishoroad	0.60	1.00																	
sexhhh	-0.17	-0.09	1.00																
agehhh	0.07	0.15	0.06	1.00															
educhhh	-0.14	-0.09	0.23	-0.44	1.00														
menumb	0.04	0.07	0.30	0.28	0.00	1.00													
aenumb	0.06	0.06	0.35	0.18	0.07	0.74	1.00												
tcultland	0.01	-0.05	0.32	0.28	-0.05	0.49	0.45	1.00											
nplot	-0.10	-0.11	0.37	0.08	0.15	0.21	0.23	0.61	1.00										
irrigland	-0.04	-0.10	0.24	0.17	0.14	0.37	0.31	0.61	0.40	1.00									
oxen	-0.02	-0.06	0.43	0.14	-0.01	0.53	0.55	0.56	0.42	0.38	1.00								
tlu	-0.12	-0.08	0.43	0.06	0.06	0.52	0.56	0.55	0.40	0.41	0.85	1.00							
offfarm	-0.06	-0.14	-0.12	-0.19	0.09	-0.03	-0.02	-0.31	-0.24	-0.23	-0.17	-0.14	1.00						
thhasset	-0.12	-0.12	0.33	-0.02	0.07	0.31	0.31	0.32	0.36	0.27	0.45	0.48	0.02	1.00					
agritechadop	-0.29	-0.16	0.32	-0.04	0.12	0.24	0.26	0.28	0.35	0.17	0.41	0.39	-0.08	0.28	1.00				
radio	-0.28	-0.18	0.41	-0.09	0.20	0.31	0.30	0.26	0.33	0.30	0.31	0.40	-0.01	0.35	0.43	1.00			
davisit	-0.29	-0.14	0.38	0.05	0.13	0.25	0.24	0.33	0.44	0.29	0.28	0.37	0.02	0.33	0.48	0.69	1.00		
creditp	0.07	0.22	-0.03	-0.09	0.09	0.05	0.07	0.06	0.05	0.03	-0.04	0.02	0.04	-0.02	0.02	-0.09	-0.08	1.00	
agesq	0.07	0.14	0.06	0.79	-0.44	0.20	0.10	0.25	0.07	0.14	0.09	0.00	-0.19	-0.05	-0.05	-0.12	0.05	-0.10	1.00

Innovative Risk-Reduction Measures and Urban Welfare in Wastewater-Irrigated Agriculture: An Endogenous Switching Regression Approach for Nairobi, Kenya

Ezekiel N. Ndunda and Eric D. Mungatana

Abstract: This paper examines the *ex post* impact of adopting innovative risk-reduction measures in wastewater irrigation on consumption expenditure and crop income in urban and peri-urban Kenya. The study relies on cross-sectional data of 317 households, which was obtained in a survey conducted between December 2011 and February 2012, in the Motoine-Ngong River basin in Nairobi. Using propensity score matching and endogenous switching regression methods, the results show that adopting risk-reduction measures in wastewater irrigation significantly increases consumption expenditure and crop income. These results are consistent with the perceived role of urban and peri-urban agriculture, in improving many livelihoods through increased per capita consumption expenditure and income of the urban farm households. The study supports increased investment in agricultural research in order to develop appropriate technologies for utilization in urban wastewater irrigation. However, there is need for policy-makers to acknowledge wastewater as a vital resource in order for many poor urban and peri-urban farmers to embrace risk-reduction technologies.

Keywords: Consumption expenditure, endogenous switching regression, propensity score matching, risk-reduction measures, and wastewater irrigation.

1. Introduction

The reuse of wastewater to compensate for scarce freshwater resources is widespread in many developing countries. Millions of poor urban dwellers have their livelihoods dependent on mostly untreated wastewater for irrigation agriculture (Jiménez and Asano 2008; Scott et al. 2004). This is mainly because wastewater is a reliable source of water supply and vital nutrients for the agricultural crops. In addition to providing an opportunity for increased food security, wastewater irrigation offers a low-cost sanitary process of municipal wastewater disposal, which also reduces direct wastewater pollution of rivers and other surface water sources. Plenty of literature supports the utilization of wastewater for irrigation agriculture (Drechsel et al. 2008; Ensink et al. 2003; Faruqui et al. 2004; Feenstra et al. 2000; Po et al. 2004; Tiongco et al. 2009; van der Hoek et al. 2002). However, there are growing health and environmental concerns for urban farmworkers in persistent contact with wastewater as well as consumers of wastewater produced foods and neighbouring inhabitants, as a result of groundwater pollution (Blumenthal and Peasey 2002; WHO 2006). This is

because wastewater used for irrigation agriculture may contain skin irritants and toxic chemicals, pesticides and pesticide residues, and excreta-related pathogens such as viruses, bacteria, protozoan, and multicellular parasites.

Population growth rate in Kenya is, on average, 2.6 per cent per annum and is projected to reach 85.4 million by the year 2050 (NCAPD 2010). However, the urban population growth rate is about 7.05 per cent per annum, with 45 per cent of the population concentrated in Nairobi. Due to rapid population growth, urbanization and economic development, there is unprecedented production of wastewater by domestic, industrial and commercial sectors, which has outpaced the rate of sewage infrastructure development despite increased investment in improved wastewater management. Although water quality management is a policy issue of high priority and major concern to Nairobi Municipality, there are insufficient resources to treat most of the generated urban wastewater. Only about 45 per cent of wastewater generated by households and industry in Nairobi is treated before it is discharged into rivers or used for irrigation agriculture (ADB 2010; UNEP 2003). This phenomenon is also common in many other cities in less developed countries where population growth has outpaced deliberate planning processes (Qadir et al. 2007; Scott et al. 2004). Therefore, the urban and peri-urban farmers in Nairobi rely mainly on untreated wastewater, directly or indirectly, for irrigation agriculture. This poses serious health concerns due to high intensity and duration of exposure to the effluent and contaminated soils.

Conventional wastewater treatment is considered the main solution to health risks in wastewater-irrigated agriculture (Barcelo' and Petrovic 2011; Hammer and Hammer 2008; Mara 2004; Patwardhan 2008). However, the implementation of conventional wastewater treatment in Nairobi has a negligible effect due to inadequate coverage, under-resourced institutions, poor human capacities, and austere financial limitations. Consequently, enormous quantities of untreated wastewater are discharged into urban drainage systems and the Nairobi River basin, which farmers rely on for irrigation agriculture. The non-conventional wastewater treatment measures seem, in the absence of conventional wastewater treatment, to be a reliable approach in reduction of the health and environmental risks presented by wastewater irrigation. Some of the common risk-reduction measures utilized by urban farmers include employing on-farm systems for wastewater treatment, wearing protective clothing while in the farm, using safer methods to draw and apply wastewater in the farm, imposing a minimum period of no irrigation immediately prior to harvest, and applying crop restrictions in wastewater-irrigated agriculture (Keraita et al. 2008; WHO 2006). The health risks for farmworkers and consumers of wastewater-produced foods can be reduced by adoption of farm-based technologies. However, the welfare effect of adopting risk-reduction measures is relatively unknown.

Several studies on wastewater-related research in Kenya have, to date, concentrated on the technical aspects and related issues of water quality improvements (Allen and Ngonga 2003; Cornish and Kielen 2004; Dulo 2008; Gathuru and Nduati, 2001; Hide et al. 2001; Karanja et al. 2010; Kilelu 2004; Obudho and Kauti 2002). The dearth of reliable information on social perspectives of recycled wastewater in the country poses a serious impediment to wastewater reuse for irrigation agriculture. Based on the health and environmental risks related to wastewater irrigation and the significance of pursuing actual and suitable mitigation strategies, it is imperative not only to understand farmers' perceptions, but to analyze the welfare impacts of specific risk-reduction measures. However, the unobserved heterogeneity and possible endogeneity pose a major challenge in the analysis of welfare impacts of adopting risk-reduction measures in wastewater irrigation. This is because although the utilization of risk-reduction measures might lead to welfare improvement for wastewater users, enhanced livelihoods may contribute towards the adoption of risk-reduction technologies in wastewater irrigation. Therefore, it is important to consider the unobserved heterogeneity, which may contribute greatly towards the welfare outcomes between the adopters and non-adopters of risk-reduction irrigation measures. Failure to account for unobserved heterogeneity may lead to flawed results, hence poor policy formulation.

This paper intends to contribute to the literature by providing a perspective on the effect of adopting risk-reduction irrigation technologies on consumption expenditure and crop income of urban and peri-urban farmers involved in wastewater irrigation in the Motoine-Ngong River basin. The study provides a perspective on the welfare impact of risk-reduction measures adopted in urban wastewater irrigation. An analysis of the effect of wastewater irrigation on livelihoods of the poor urban and peri-urban farmers is important in informing policy-makers about various dimensions of the practice. To achieve the objective, this study applied both the propensity score matching model and an endogenous switching regression model to obtain robust results. The use of the propensity score matching model ensured that the variations of characteristics of farmers who had adopted risk-reduction measures and those who did not adopt the risk-reduction measures were excluded in analysis. This provided a plausible counterfactual group of farmers for comparison with the adopters of risk-reduction technologies for wastewater irrigation in the study area (Rosenbaum and Rubin 1985). The endogenous switching regression model was used in this study to account for the unobservable bias that affects the choice of risk-reduction irrigation technologies in wastewater reuse and also the crop husbandry decisions by wastewater users (Maddala and Nelson 1975). This regression method, which depends on the joint normality of error terms, enables a simultaneous estimation of the binary and continuous specifications of the model, thus yielding consistent standard errors (Lokshin and Sajaia 2004).

The rest of this paper is structured as follows. Section two provides a brief description of the case study area, whilst survey design and data is presented in section 3. The econometric model employed is described in section 4, and the results are presented in section 5. The final section presents conclusions drawn from the study.

2. Research Method and Materials

The case study area is the Motoine-Ngong River basin, situated in the western region of Nairobi County, in Kenya. The total area, of about 127 square kilometres from the source to the confluence with Nairobi River, is characterized by various land use activities, such as farmlands, forest and grasslands. Motoine-Ngong River marks the southern boundary of the Kibera slum, one of the major informal settlements in Nairobi. Kibera slum, with an area of 250 hectares, has 11 villages, namely Kianda, Gatwikera, Silanga, Lindi, Kisumu Ndogo, Kambi Muru, Makina, Mashimoni, Soweto-Highrise, Soweto, and Laini Saba. This informal settlement is the largest slum in Kenya but has an extremely poor sanitation infrastructure, hence making it a major source of water pollution. The Motoine-Ngong River is characterized by heavy pollution due to human waste from the nearby Kibera slum, industrial waste and effluent from over-flowing sewers. Most farmers in the informal settlement rely on wastewater, either directly or indirectly, for irrigation agriculture.

Survey research design was used to evaluate the impact of wastewater irrigation welfare of urban and peri-urban farmers in Nairobi. Since the survey research is empirical, specific information about the urban and peri-urban farmers was obtained using semi-structured questionnaires with closed and open-ended questions. Farmers who practise irrigated agriculture in the city were classified into two strata: those who have adopted risk-reduction measures in wastewater irrigation agriculture and others who have not adopted the practice. Units of research in this study were farm households that are involved in urban and peri-urban agriculture in Nairobi. A purposive sampling method was used to select farmers who practise urban and peri-urban agriculture in Kibera slum. This was mainly because the slum is home to many urban dwellers, whose livelihoods are dependent on wastewater irrigation agriculture. The farmers were then randomly selected to ensure that all wastewater users in the study area were offered equal opportunity of participation.

The survey data for this paper was obtained from a case study conducted between December 2011 and February 2012, in the Motoine-Ngong River basin in Nairobi. This involved the farmers who rely on the wastewater from sewer systems or the heavily polluted Motoine-Ngong River, for irrigation agriculture. A total of 317 farm households involved in wastewater reuse for agriculture were randomly sampled from all the villages. A discussion with farmers and wastewater treatment staff in Kariobangi and Dandora wastewater treatment plants preceded the actual

data collection. This provided important information for the study and also enabled improvement of the survey instrument for household data collection. Some of the factors considered in the household survey were household, farm, institutional characteristics, and welfare outcomes (consumption expenditure and crop income) of the involved households. Personal interviews with farmers involved in wastewater irrigation agriculture were conducted with the help of enumerators. In order to minimize enumerator bias in data collection, all the enumerators were trained on the questionnaire administration before the actual data collection commenced.

3. Econometric Models for Impact Evaluation

3.1 Data Analysis

The estimation of welfare gain by adoption of risk-reduction measures in urban wastewater irrigation involves endogeneity as well as sample selection (Hausman 1978; Heckman 1979). Since an endogenous switching regression model accounts for both endogeneity and sample selection, it was estimated to measure the household consumption expenditure and crop income. In order to ensure robustness of assessment, this study also used propensity score matching, which is a non-parametric technique, to analyze the welfare outcome.

3.1.1 Propensity Score Matching Model

The adoption of risk-reduction measures in wastewater irrigation might be an important approach in improvement of livelihoods of many urban and peri-urban farm households in Kenya. Experimental data can provide sufficient information on the counterfactual situation that would solve the problem of causal inference in wastewater irrigation. Since experimental data on adoption of wastewater risk-reduction measures in the study area is not available, this study estimated the direct welfare effect through an evaluation of per capita consumption expenditure and crop income across the farm households. The causal effect of adoption of risk-reduction measures on consumption expenditure could be evaluated as the difference in average consumption expenditure between adopters and non-adopters, if adoption was randomly assigned to farm households in an experiment. Similarly, the causal effect of adoption of risk-reduction measures on crop income could be evaluated as the difference in average crop income between adopters and non-adopters, if adoption was randomly assigned to farm households in an experiment.

In an experiment, this problem may involve a random assignment of the farmers to treatment and control categories, where the welfare outcome observed on the control households statistically represents what would have occurred without adoption. However, farmers make independent adoption choices, hence they are not randomly distributed to the two clusters. Since farmers who have adopted risk-reduction measures as well as those who

have not, may be systematically different, potential self-selection bias may make it hard to evaluate the gains from adoption of risk-reduction measures on observational data. In order to account for selection bias from the observable covariates, this study used propensity score matching method. This was meant to compare the observed outcomes of the adopters of risk-reduction measures with the outcomes of counterfactual non-adopters.

In propensity score matching technique, conditions of randomized experiment are created in order to evaluate a causal effect as in a controlled experiment (Heckman et al. 1998; Wooldridge 2005). Propensity score matching model contrasts the instrumental variables and Heckman models by adopting the conditional assumption in order to eradicate the sample selection bias in observable covariates (Heckman and Navarro 2004). In this study, the propensity scores for adopters of risk-reduction measures were initially estimated for each covariate and then matched with those of non-adopters of the risk-reduction measures. This enabled the study to evaluate the average treatment effect for the treated. Since there are variations in using different propensity score matching methods (Caliendo and Kopeinig 2008), this study employed the kernel-based matching and nearest neighbour matching.

If Y^1 denotes the value of welfare when farm household i is subject to treatment ($D=1$) and Y^0 , the welfare when the household does not adopt risk-reduction measures in wastewater irrigation ($D=0$), the welfare that is observed in the farm households can be presented as:

$$Y = DY^1 + (1 - D)Y^0 \quad (1)$$

where Y^1 is observed if ($D=1$) and Y^0 is observed if ($D=0$). Therefore, the average effect of treatment on the treated (ATT) is expressed as follows:

$$ATT = E(Y^1 - Y^0 / D = 1) = E(Y^1 / D = 1) - E(Y^0 / D = 1) \quad (2)$$

The estimation of propensity score is:

$$P(X) = \Pr(D = 1 / X) \quad (3)$$

Since we can only observe the outcome variable of adopting the risk-reduction measures $E(Y^1 / D=0)$, the outcome of adopters had they not adopted cannot be observed $E(Y^0 / D=1)$. The propensity score matching estimation matches treatment and control by assuming counterfactual analysis of both categories. The Conditional Independence Assumption (CIA) is the principal assumption behind the matching estimators in propensity score matching, and states that the decision to adopt is random,

conditional on observed covariates X . The CIA is symbolised as: $(Y^1, Y^0) \perp D/X$. The set of X s comprises of all the covariates that influence the welfare indicators with no-treatment as well as the selection into treatment. Therefore, every adopter of risk-reduction intervention is assured a counterfactual in the population of non-adopter farmers. Given X , the likely welfare outcomes are not dependent on the adoption of risk-reduction measures. There exists a positive probability for wastewater farmers who adopt risk-reduction interventions and those who do not, for all X s. This implies that:

$$E(Y^0/D=1, P(X)) = E(Y^0/D=0, P(X)) \quad (4)$$

where $0 < P(X) < 1$

Computing the ATT:

$$ATT = E((Y^1 - Y^0)/X, D=1) = E(Y^1/X, D=1) - E(Y^0/X, D=1) \quad (5)$$

where Y^1 represents the treated outcome, Y^0 represents the untreated outcome, D specifies the status of treatment such that $D=1$ if individuals receive treatment, and zero otherwise. The curse of dimensionality can be reduced by matching along the propensity scores instead of matching along the covariates (Angrist and Pischke 2009; Rosenbaum and Rubin 1983).

Rearranging equation (5):

$$\begin{aligned} ATT &= E(Y^1 - Y^0/D=1) = E[E(Y^1 - Y^0/D=1, P(X))] \\ &= E[E(Y^1/D=1, P(X)) - E(Y^0/D=0, P(X))] \end{aligned} \quad (6)$$

Equation (6) explains that average treatment effect for the treated is the difference between the welfare indicator for the observable treated group and the welfare indicator for the treated group, had it not been treated. The welfare indicator for the treated group, had it not been treated, is unobservable and hence it requires treatment. Since the main purpose for propensity score matching estimation is to ensure uniformity of characteristics in both the adopters of risk-reduction measures and the non-adopters, the matched comparison group is a plausible counterfactual (Ali and Abdulai 2010; Lee 2008).

3.1.2 Endogenous Switching Regression Model

Microeconomic analysis of the effects of urban wastewater irrigation on livelihoods of farm households is hampered by the fact that the condition

prior to irrigation and that after irrigation are rarely observed. Since the choice to reuse wastewater for agriculture is voluntary, the sample selection bias problem may arise as farmers who use wastewater are also likely to be the ones who find the resource profitable. Propensity score matching is controlled for the observed variables, in comparing the difference between welfare of wastewater users and freshwater users in the study area. However, if unobservable characteristics that influence the decision to adopt a risk-reduction measure and the outcome variable exist, a hidden bias may lead to a mismatch and inefficient estimation of welfare impacts (Rosenbaum 2002). This study employed an endogenous switching regression model to account for hidden bias since it can affect the wastewater irrigation and production decisions by wastewater users (Maddala and Nelson 1975).

If we let the adoption of risk-reduction measures be a dichotomous choice resulting from utility maximization, and the utility is determined by exogenous variables, the adoption decision can be modelled as:

$$I_i^* = \lambda Z_i + \varepsilon_i \quad \text{with } I_i^* = \begin{cases} 1 & \text{if } I_i^* > 1 \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

Where I_i^* denotes a latent variable that determines adoption of risk-reduction measures in wastewater irrigation; vector Z_i represents the exogenous farm and non-farm characteristics determining adoption of risk-reduction measures in wastewater irrigation; λ symbolises the vector of farm and non-farm characteristics; and ε_i is random disturbance associated with the adoption of risk-reduction measures.

In equation (7), I_i^* is a latent factor that is equivalent to 1, if farm household i adopts risk-reduction measures in irrigation, and equals zero otherwise.

The distinct equations for welfare outcomes that accounts for selection bias are:

$$Y_{1i} = g(X_{1i}, \alpha_i) + \eta_{1i} \quad \text{if } I_i^* = 1 \quad (8a)$$

$$Y_{2i} = h(X_{2i}, \beta_i) + \eta_{2i} \quad \text{if } I_i^* = 0 \quad (8b)$$

where variables Y_{1i} and Y_{2i} indicate the consumption expenditure per adult equivalent and crop income when farmers have either adopted or not adopted risk-reduction measures in wastewater irrigation; $g(X_{1i}, \alpha_{1i})$ and $h(X_{2i}, \alpha_{2i})$ are equations for farm households per capita consumption expenditure and crop income for farmers who have adopted risk-reduction

measures in wastewater irrigation and those who have not adopted, respectively. The parameters that will be estimated are: α , β and λ , while ε_i , η_{1i} and η_{2i} are error components, which are considered to have a trivariate normal distribution with mean vector zero and covariance matrix:

$$\text{cov}(\varepsilon_i, \eta_{1i}, \eta_{2i}) = \begin{pmatrix} \sigma_\varepsilon^2 & \sigma_{1\varepsilon} & \sigma_{2\varepsilon} \\ \sigma_{1\varepsilon} & \sigma_1^2 & . \\ \sigma_{2\varepsilon} & . & \sigma_2^2 \end{pmatrix} \quad (9)$$

where σ_ε^2 is the variance of the error term in the selection function (7); σ_1^2 and σ_2^2 are the variances of error terms in the welfare outcome equations (8a) and (8b); and $\sigma_{1\varepsilon}$ and $\sigma_{2\varepsilon}$ represent the covariance of ε_i , η_{1i} and η_{2i} . Since the coefficients are estimable only up to a scale factor, σ_ε^2 is assumed to be equal to 1. Maddala (1983) explains that the covariance between η_{1i} and η_{2i} is undefined since Y_{1i} and Y_{2i} are not observed concurrently. The expected values of η_{1i} and η_{2i} conditional on sample selection are:

$$E[\eta_{1i}/I_i^* = 1] = \sigma_{1\varepsilon} \frac{\phi(\lambda'Z_i)}{\Phi(\lambda'Z_i)} = \sigma_{1\varepsilon}\gamma_{1i} \quad (10)$$

$$E[\eta_{2i}/I_i^* = 0] = -\sigma_{2\varepsilon} \frac{\phi(\lambda'Z_i)}{(1 - \Phi(\lambda'Z_i))} = \sigma_{2\varepsilon}\gamma_{2i} \quad (11)$$

$$\text{where } \gamma_{1i} = \frac{\phi(\lambda'Z_i)}{\Phi(\lambda'Z_i)} \text{ and } \gamma_{2i} = \frac{\phi(\lambda'Z_i)}{(1 - \Phi(\lambda'Z_i))}$$

Therefore, if there exists unobserved covariates that affect the considered welfare outcomes and decision to adopt risk-reduction measures in wastewater reuse, η_{1i} and η_{2i} will be correlated with ε_i . The error components in equations (8a) and (8b), conditional on the sample selection condition, have a non-zero expected value. This implies that Ordinary Least Squares (OLS) estimates of the coefficients in the per capita consumption expenditure and crop income equations will be biased. The equations (8a) and (8b) are augmented to eradicate the hidden bias linked to non-random sample selection:

$$Y_{1i} = g(X_{1i}, \alpha_i) + \sigma_{1\varepsilon} \frac{\phi(\lambda'Z_i)}{\Phi(\lambda'Z_i)} + \psi_{1i} \quad \text{if } I_i^* = 1 \quad (12)$$

$$Y_{2i} = h(X_{2i}, \beta_i) + \sigma_{2\varepsilon} \frac{-\phi(\lambda' Z_i)}{(1 - \Phi(\lambda' Z_i))} + \psi_{2i} \quad \text{if } I_i^* = 0 \quad (13)$$

where $\phi(\lambda' Z_i)$ and $\Phi(\lambda' Z_i)$ are respectively normal probability and cumulative density functions; $\psi_1 = \eta_1 + \sigma_{1\varepsilon}$ and $\psi_2 = \eta_2 + \sigma_{2\varepsilon}$ are new error terms; and $\phi(\lambda' Z_i)/\Phi(\lambda' Z_i)$ and $-\phi(\lambda' Z_i)/(1 - \Phi(\lambda' Z_i))$ are known as the Inverse Mill's Ratios (IMR). The coefficients of the IMR, $\sigma_{1\varepsilon}$ and $\sigma_{2\varepsilon}$ provide the correlation between risk-reduction decision and the welfare outcomes. According to Lokshin and Sajaia (2004), Full Information Maximum Likelihood (FIML) estimation is an efficient method to analyse endogenous switching regression models. The FIML method estimates the Probit criterion or selection equation and the regression equations in order to yield consistent standard errors. The logarithmic likelihood functions for the system of equations (7, 8a and 8b), given the trivariate normal distribution for the error terms, is given in equation (14):

$$LnL_i = \sum_{i=1}^N I_i^* \left[\ln \phi \left(\frac{\eta_{1i}}{\sigma_1} \right) - \ln \sigma_1 + \ln \Phi(\gamma_{1i}) \right] + (1 - I_i^*) \left[\ln \phi \left(\frac{\eta_{2i}}{\sigma_2} \right) - \ln \sigma_2 + \ln(1 - \Phi(\gamma_{2i})) \right] \quad (14)$$

$$\text{where } \gamma_{ji} = \frac{(\lambda Z_i + \rho_j \eta_{ji} / \sigma_j)}{\sqrt{(1 - \rho_j^2)}} \quad j = 1, 2$$

The term $\rho_1 = \sigma_{1\varepsilon}^2 / \sigma_{\varepsilon} \sigma_1$ represents the correlation coefficient between ε_i and η_{1i} and $\rho_2 = \sigma_{2\varepsilon}^2 / \sigma_{\varepsilon} \sigma_2$ is the correlation coefficient between ε_i and η_{2i} .

4. Results

4.1 Descriptive Analysis

The means of variables selected for adopters and non-adopters of risk-reduction measures in wastewater irrigation agriculture were compared using the t-test (Table 1).

Table 1. Descriptive Summary of Variables used in Estimations

Variable	Adopters (N=121)	Non-adopters (N=196)	T-test
Dependent variable			
Consumption expenditure per adult equivalent ('000 Kshs)	5.52	4.33	1.73**
Monthly crop income per adult equivalent ('000 Kshs)	3.01	1.77	1.50**
Household characteristic variables			
Household size	4.88	4.34	2.79***
Age of household head (years)	41.27	39.16	0.09
Gender of household head (male=1)	0.77	0.80	0.79
Education level of household head (years)	8.60	7.27	2.11***
Farm characteristic variables			
Land is privately owned (yes=1)	0.37	0.15	1.70**
Farm size (acres)	0.47	0.49	0.63
Main occupation is farming (yes=1)	0.53	0.68	2.62***
Farming experience (years)	5.81	4.58	1.73**
Institutional characteristic variables			
Contact with government extension agents (yes=1)	0.28	0.25	0.47
Member of a farmers' association (yes=1)	0.54	0.25	5.60***
Contact with local NGO (yes=1)	0.36	0.16	4.13***
Access to credit (yes=1)	0.56	0.14	8.85***
Access to certified seeds (yes=1)	0.61	0.36	4.57***
Access to media (yes=1)	0.57	0.32	4.60***
Aware of risks in wastewater irrigation (yes=1)	0.64	0.41	4.20***

SOURCE: Survey data (2013)

Note: ***, **, * Significant at 1 per cent, 5 per cent and 10 per cent levels, respectively.

The randomly selected sample of 317 farm households included about 38 per cent of farmers who had adopted a non-conventional technique, to reduce the risks associated with untreated wastewater irrigation. The mean household size for adopters is 4.88 and 4.34 for non-adopters and the difference is statistically significant. This may be used to explain the importance of household labour in adoption of a risk-reduction measure in wastewater irrigation. On average, the age of household head is about 41.27 years for adopters and 39.16 years for the non-adopters. However, the difference in age of household heads is not statistically significant although the adopters are observed to be older than non-adopters. This shows that age of the household head is not a major factor in adoption decision for farmers. Most of the farm households of adopters and non-adopters are averagely male-headed and the difference in gender composition in both groups is not statistically significant. The mean education level of household head is 8.60 years for adopters and 7.27 years for non-adopters of risk-reduction measure in wastewater reuse for agriculture. Since the difference in mean education level for adopters and non-adopters is statistically significant, this suggests that education level of household heads might be correlated with the decision to adopt.

The land used by adopters and non-adopters of risk-reduction measures to practise urban agriculture in Nairobi is not privately owned, and the difference in ownership is statistically significant. This shows that land ownership for urban agriculture correlated to decision to adopt. Average farm size for farm households is 0.47 acres for adopters and 0.49 acres for non-adopters but the difference is not statistically significant. Mean farming experience for household head is about 5.81 years for adopters and 4.58 years for non-adopters, and the difference is statistically significant, hence underlining the importance of farming experience in adoption of risk-reduction technologies in wastewater irrigation. Access to extension services was low for farmers involved in urban wastewater irrigation in Nairobi. However, the adopters of risk-reduction measures seem to have higher contact with government extension agents than the non-adopters although their difference is not statistically significant. The membership to farmers' associations is significantly higher for adopters than for non-adopters of risk-reduction measures. This shows that membership to farmers' association in urban agriculture may be correlated with the decision to adopt safe irrigation practices in wastewater reuse.

Adopters have significantly more contact with the local non-governmental organizations (NGOs) than non-adopters of risk-reduction technologies. This statistically significant contact with local NGOs suggests that the adopter farmers have greater access to information relevant for safe wastewater reuse in agriculture. Access to credit is significantly higher for adopters than for non-adopters, supporting the importance of credit facilities for adoption of risk-reduction measures in wastewater irrigation. The adopters have higher access to certified seeds than the non-adopters

and the difference is statistically significant. This implies that access to certified seeds might be correlated with a decision to adopt. Access to media is higher for adopters than non-adopters and the difference is statistically significant. This indicates that access to media for wastewater users is interrelated with the decision to adopt risk-reduction measures. Awareness to risks of wastewater irrigation is significantly higher for adopters of on-farm interventions than for non-adopters. This significant difference suggests that risk awareness is correlated with the decision of wastewater users to adopt safe practices in urban agriculture.

4.2 Econometric Analysis

The propensity score matching technique was employed in the estimation of values of average treatment effect on the treated (ATT) of consumption expenditure and crop income. A Probit regression model was initially estimated, whereby the response variable was one if the farm household adopted a risk-reduction technology in wastewater irrigation, and zero otherwise. In order to ensure that the observations of adopters and non-adopters have similar distribution, this study relied on the balancing properties of propensity scores for robust specifications. In order to conduct the balancing test in this study, a t-test was employed to assess the equality of the means of considered variables across the classified sets of propensity scores. The common support sample for creation of match was obtained after the Probit model was estimated again and balancing properties rechecked. This study employed both the kernel and nearest neighbour matching procedures in the impact analysis.

According to the results, propensity score matching results show that the adoption of a risk-reduction measure in wastewater irrigation has a positive impact on the consumption expenditure and crop income (Tables 2 and 3). The results from Kernel ($p=0.057$) and Nearest Neighbour Matching ($p=0.177$) methods show that the causal impact of adopting risk-reduction measures in wastewater irrigation on consumption expenditure was not statistically significant. Similarly, the causal impact of adopting risk-reduction measures in wastewater irrigation on crop income was not significant using the Nearest Neighbour Matching method ($p=0.276$). However, using the Kernel Matching ($p=0.047$) method shows a statistically significant causal impact of adopting risk-reduction measures in wastewater irrigation on crop income.

Table 2. Impact of risk-reduction technology adoption on consumption expenditure

Matching method	Adopters (N=121)	Non-adopters (N=196)	Difference (ATT)	S.E.	T-test
Kernel matching	8.0697	7.2848	0.7849	0.4131	1.90*
Nearest neighbour	8.0733	7.4109	0.6624	0.4897	1.35

Response variable: Log consumption expenditure per adult equivalent unit

SOURCE: Survey data (2013)

Note: ***, **, * Significant at 1 per cent, 5 per cent and 10 per cent levels, respectively.

Table 3. Impact of risk-reduction technology adoption on crop income

Matching method	Adopters (N=121)	Non-adopters (N=196)	Difference (ATT)	S.E.	T-test
Kernel matching	6.1970	5.9319	0.2651	0.1334	1.99**
Nearest neighbour	6.1969	5.8207	0.3761	0.3458	1.09

Response variable: Log crop income per adult equivalent unit

SOURCE: Survey data (2013)

Note: ***, **, * Significant at 1 per cent, 5 per cent and 10 per cent levels, respectively.

This study shows that the adopters of risk-reduction measures in wastewater irrigation agriculture, gain in consumption expenditure per adult equivalent and crop income per adult equivalent, compared to non-adopters. The gain in consumption expenditure per adult equivalent for adopting farmers ranges from 0.66 for Nearest Neighbour to 0.78 for Kernel Matching algorithm. Also, the improvement in crop income per adult equivalent for adopting farmers ranges from 0.27 for Kernel Matching algorithm to 0.38 for Nearest Neighbour algorithm. However, the results fail to support a significant positive causality between welfare outcomes (consumption expenditure and crop income) and adoption of risk-reduction technologies in wastewater-irrigated agriculture. This weak positive causality may be partly attributed to the inability of propensity score matching method to provide consistent estimates in the presence of unobserved selection bias in survey data.

In order to control for the hidden bias, this study employed the endogenous switching regression model (Tables 4 and 5). This involved the application of the full information maximum likelihood method to evaluate the impact of adopting a risk-reduction measure on consumption expenditure per

capita and crop income per capita in wastewater irrigation. Results for the estimated coefficients of selection equation (7) on the adoption or non-adoption of risk-reduction technologies in wastewater irrigation are presented in the first column. Also, the estimated coefficients of consumption expenditure and crop income equations (8a and 8b) for adopters and non-adopters of risk-reduction measures are provided in the second and third columns, respectively.

Table 4. Full Information Maximum Likelihood Estimation of the switching regression

Variables	FIML Endogenous Switching Regression		
	Adoption (1/0)	Adoption=1 (Adopters)	Adoption=0 (Non-adopters)
Household size	-0.125(0.06)**	-0.104(0.06)**	-0.147(0.06)**
Age of household head (years)	-0.015(0.01)	0.048(0.01)***	0.020(0.01)**
Gender of household head (male=1)	0.095(0.21)	-0.271(0.17)	-0.770(0.25)***
Education level of household head (years)	0.044(0.03)	0.021(0.03)	0.0004(0.04)
Land is privately owned (yes=1)	0.186(0.39)	0.052(0.30)	0.192(0.45)
Farm size (acres)	-0.015(0.32)	1.545(0.29)***	1.310(0.37)***
Crop income per adult equivalent (*000 Kshs)	0.163 (0.08)**	0.113(0.07)*	-0.165(0.10)*
Main occupation is farming (yes=1)	-0.115(0.18)	-0.477(0.15)***	-0.275(0.21)
Farming experience (years)	0.027(0.02)	-0.074(0.01)***	-0.039(0.03)
Contact with government extension agents (yes=1)	-0.127(0.17)		
Member of a farmers' association (yes=1)	0.556(0.17)***		
Contact with local NGO (yes=1)	0.529(0.17)***		
Access to credit (yes=1)	1.303(0.18)***		
Access to certified seeds (yes=1)	0.416(0.15)***		
Access to media (yes=1)	0.405(0.16)**		
Aware of risks in wastewater irrigation (yes=1)	0.596(0.16)***		
Constant	-1.965(0.74)**	6.703(0.63)***	8.395(0.85)***
Diagnostics			
Sigma_1	0.882(0.06)***		
Sigma_2	1.255(0.10)***		
Rho_1	-0.518(0.17)***		
Rho_2	-0.798(0.11)***		
Log likelihood	-573.403***		
Number of observations	317		

SOURCE: Survey data (2013)

Notes: ***, **, * Significant at 1 per cent, 5 per cent and 10 per cent levels, respectively. Dependent variable: Risk-reduction technology adoption and log consumption expenditure per adult equivalent. Absolute values of robust standard errors are in parentheses.

Table 5. Full Information Maximum Likelihood Estimation of the Switching Regression

Variables	FIML Endogenous Switching Regression		
	Adoption (1/0)	Adoption=1 (Adopters)	Adoption=0 (Non-adopters)
Household size	-0.274(0.06)***	-0.406(0.06)***	-0.238(0.05)***
Age of household head (years)	-0.007(0.01)	0.011(0.01)	0.009(0.01)
Gender of household head (male=1)	0.045(0.22)	-0.358(0.19)*	-0.107(0.23)*
Education level of household head (years)	0.122(0.04)***	0.411(0.20)**	0.038(0.01)***
Land is privately owned (yes=1)	0.217(0.11)**	0.254(0.09)***	0.221(0.11)**
Farm size (acres)	0.147(0.03)***	0.308(0.13)**	0.893(0.33)***
Main occupation is farming (yes=1)	-0.489(0.02)**	-0.031(0.17)	-0.001(0.19)
Farming experience (years)	0.041(0.20)*	0.203(0.12)*	0.036(0.02)
Contact with government extension agents (yes=1)	-0.217(0.19)		
Member of a farmers' association (yes=1)	0.773(0.20)***		
Contact with local NGO (yes=1)	0.556(0.22)***		
Access to credit (yes=1)	1.002(0.21)***		
Access to certified seeds (yes=1)	0.424(0.19)**		
Access to media (yes=1)	0.499(0.18)***		
Aware of risks in wastewater irrigation (yes=1)	0.904(0.20)***		
Constant	-0.881(0.62)	7.345(0.52)***	6.121(0.64)***
Diagnostics			
Sigma_1	0.906(0.06)***		
Sigma_2	1.066(0.05)***		
Rho_1	-0.776(0.23)***		
Rho_2	-0.968(0.31)***		
Log likelihood	-581.726***		
Number of observations	317		

SOURCE: Survey data (2013)

Notes: ***, **, * Significant at 1 per cent, 5 per cent and 10 per cent, respectively. Dependent variable: Risk-reduction technology adoption and log crop income per adult equivalent. Absolute values of robust standard errors are in parentheses.

In order to assess whether the estimated coefficients, as a grouping, are different between the equations of adopters and non-adopters of risk-reduction measures, a Wald test was used in this study. This test shows that the difference between the consumption expenditure equation of adopters of risk-reduction technologies and the consumption function of the non-adopters of the technologies is statistically significant ($\chi^2=573.403$; $p=000$; $df=16$). Also, the test indicates that the difference between the crop income equation of adopters of risk-reduction technologies and the crop income function of the non-adopters of the technologies is statistically significant ($\chi^2=581$; $p=000$; $df=16$). The null hypothesis that all slope coefficients of the three estimated equations are equal to zero was rejected by the likelihood ratio test for joint independence ($\chi^2=21.50$; $p=000$) in consumption expenditure and ($\chi^2=38.46$; $p=000$) in crop income. Moreover, the off-diagonal values of the error covariance matrix and the error correlations were significant ($p=000$), which validated the simultaneous modelling based on endogenous switching regression technique.

The results of endogenous switching regression model show that the coefficient of household size is negative and significant for consumption expenditure equations and the selection equation. This implies that the likelihood to adopt risk-reduction technologies in wastewater reuse decreases as the size of the household increases. Since the increase in household size constrains the household income, this results in a decline of per capita consumption expenditure. The coefficient of the age of household head was found to be positive and significant for consumption expenditure equations, and negative and insignificant for the selection equation. Therefore, the welfare of farm households declined as the age of household heads increased. Gender has a positive but non-significant impact on welfare and adoption of risk-reduction measures in wastewater irrigation. The education level of household heads in the sample was observed to be a positive but non-significant determinant of the selection equation and the welfare equations. This suggests that the increase in education level of household head has a positive impact on the decision to adopt risk-reduction measures as well as the consumption expenditure. Similarly, the coefficient of land ownership was observed to be positive but not a significant factor in determining selection equation and also welfare equations. This implies that an increase in owned land has a positive impact on the decision to adopt risk-reduction measures as well as the consumption expenditure.

Farm size is a significant aspect in consumption expenditure and the decision to choose risk reduction measures in wastewater irrigation. The coefficient of farming occupation was negative and non-significant for selection equation, but negative and significant for welfare equations. This is partly because most of the urban production of crops is for subsistence purposes, hence generates inadequate income to sustain consumption

expenditure. The farming experience of household heads had a negative and non-significant effect on selection equation as well as the welfare equations. The coefficient of contact with government extension agents was negative and not a significant determinant in the selection equation. This may be due to the fact that policy-makers do not yet recognise wastewater as a resource for urban irrigation. Membership to a farmers' association was found to significantly influence the decision to adopt risk-reduction technologies in wastewater reuse for agriculture. This may be attributed to the possibility of benefiting from the experiences of other urban farmers. Results show that the farmers who had contact with local NGOs had a positive and significant effect on adoption of risk-reduction measures in wastewater irrigation. This may be linked to access to adequate information on safe utilization of wastewater for irrigation.

Access to credit for farmers was observed to have a positive and significant effect on the selection equation. Since the technology acquisition involves some investment, access to credit provides the much-needed capital for investment in risk-reduction technologies. A positive and significant effect of access to certified seeds was observed for the decision equation. The use of certified seeds would require the adoption of appropriate technologies in order to realize optimal yields. Therefore, farmers who have access to certified seeds may have some incentive to adopt risk-reduction technologies in order to promote crop yields. The coefficient for access to media was positive and statistically significant in the selection equation. This suggests that access to media, such as television and radio, provides farmers with essential information on safe utilization of wastewater, for irrigation agriculture. The coefficient for awareness of risks in wastewater irrigation on the decision to adopt was found to be positive and significant. This shows that the decision to adopt risk-reduction measures is affected by knowledge about health and environmental risks of wastewater irrigation.

The coefficient of household size is negative and significant for crop income equations and the selection equation, according to the results of endogenous switching regression model (Table 5). This shows that the likelihood of adopting risk-reduction technologies in wastewater reuse decreases as the size of the household increases. This may be attributed to the resource constraint that leads household members to seek alternative sources of income. Based on the results from this study, age of household head was found to have a positive and significant coefficient for crop income equations and negative and insignificant for the selection equation. This implies that the welfare of farm households dropped as the age of household heads increased. Also, gender has a positive but non-significant impact on crop income and adoption of risk-reduction measures in wastewater irrigation. The coefficient of education level of household heads in the sample was observed to be a positive and significant determinant of the selection equation and the crop income equations. This shows that an increase in education level of household head has a positive impact on the decision to adopt risk-reduction measures as well as the

consumption expenditure. Similarly, the coefficient of land ownership was observed to have a positive and significant factor in determining selection equation and also welfare equations. This may be explained by the fact that an increase in land ownership has a positive impact on the decision to adopt risk-reduction measures as well as the crop income.

The coefficient for farm size is significant, which shows that the size of land under agriculture is a key factor for crop income and decision to choose risk-reduction measures in wastewater irrigation. Although the coefficient of farming occupation was negative and significant for the selection equation, it was negative and non-significant for the welfare equations. This may be explained by the fact that much of the urban and peri-urban farming is subsistence and farmers only sell the surplus produce. The farming experience of household heads had a negative and non-significant effect on selection equation as well as the crop income equations. This may be explained by the ability of farmers to acquire adequate knowledge about risk-reduction in wastewater irrigation, hence ensuring improved welfare in the practice. According to the results from this study, the coefficient of the contact with government extension agents was negative and not a significant determinant in the selection equation. This could be explained by the lack of support by policy-makers in utilization of wastewater in urban and peri-urban agriculture. The coefficient of membership to farmers' associations was significantly influential in the decision to adopt risk-reduction technologies in wastewater reuse for agriculture. This may be readily accredited to the farmer-to-farmer extension services prevalent among the urban and peri-urban farmers, which leads to improved welfare of farm households.

The endogenous switching regression results show that farmers who interacted with local NGOs had a positive and significant effect on adoption of risk-reduction measures in wastewater irrigation, and hence had increased crop income. This may be explained by the extension services and resources support offered to the farmers involved in wastewater irrigation. Also, the coefficient for access to credit by farmers was observed to have a positive and significant effect on the selection and welfare equations. This may be due to increased ability to acquire relevant equipment necessary for reduction of risks in wastewater irrigation. The coefficient of access to certified seeds was observed to be positive and significant for the decision and welfare equations. This is because the use of certified seeds requires the adoption of suitable technologies in order to realize adequate yields, and hence increased crop income. Consequently, farmers who have access to certified seeds may be motivated to embrace innovative risk-reduction technologies in order to promote crop income. The results show that the coefficient for access to media was positive and statistically significant in the selection and welfare equations. This implies that access to media, such as television and radio, provides farmers with a strategic opportunity to acquire vital information on safe practices in wastewater irrigation. Lastly, the coefficient for awareness of risks in

wastewater irrigation on the decision to adopt was found to be positive and significant. This shows that the decision to adopt risk-reduction measures is greatly influenced by the knowledge about health and environmental risks attributed to wastewater irrigation.

The correlation coefficients (ρ_1 & ρ_2) are both negative and statistically significant for the correlations between the technology choice equation and the consumption expenditure, and also the crop income equations for adopters and non-adopters. Since the correlation between technology choice equation and the consumption expenditure equation for adopters is negative and significantly different from zero, the model suggests that farmers who choose risk-reduction measures have higher consumption expenditure than a random farmer from the sample. Therefore, the adoption of risk-reduction measures leads to increased consumption expenditure and hence reduction in urban poverty. The findings are consistent with findings obtained from a study in Mexico using propensity score matching methods, which shows that the adoption of improved maize varieties increases per capita consumption expenditure while reducing poverty (Becerril and Abdulai 2010).

Similarly, the negative and significantly different from zero correlation between technology adoption equation as well as the crop income equation for adopters suggests that farmers who choose risk-reduction measures have higher crop income than a random farmer from the sample. Also, the covariance terms (σ_1 and σ_2) in both welfare models have the same sign, which suggests hierarchical sorting (Maddala 1983; Willis and Rosen 1979). The adopters of risk-reduction technologies have above-average consumption expenditure and crop income, whether they adopt or not, but they are better off adopting than not adopting. Therefore, adopting risk-reduction measures has a significant effect on the welfare of urban farmers involved in urban and peri-urban wastewater irrigation. These results compare with those obtained from a study using propensity score matching method in Uganda, which found that the adoption of improved groundnut varieties increased crop income while reducing poverty (Kassie et al. 2011). The positive and significant correlation coefficients suggest the presence of self-selection in adoption of risk-reduction measures. Therefore, the decision to adopt risk-reduction measures and consumption, as well as the crop income given the adoption decision, is influenced by both observed and unobserved characteristics. The estimated coefficients for consumption expenditure and crop income equations of adopters and non-adopters of risk-reduction measures are different, which suggests the presence of heterogeneity in the sample of farmers surveyed.

5. Conclusions

This paper relies on cross-sectional survey data collected from a randomly selected sample of 317 farm households, who are involved in urban agriculture in Nairobi, Kenya. The paper evaluates the effect of adopting

risk-reduction measures on welfare of urban farm households using consumption expenditure and crop income. In order to control selection bias in the causality analysis, this study employed both the propensity score matching and endogenous switching regression models. The findings from this study show that adoption of risk-reduction technologies and household welfare are significantly influenced by household and farm characteristics. Membership in farmers' associations, contact with local NGOs and awareness to wastewater risks are also important drivers in the choice of risk-reduction technologies. Similarly, access to credit, access to certified seeds, access to media, and risk awareness are critical aspects in adoption of risk-reduction measures in wastewater-irrigated agriculture, which merit consideration by urban planners and policy-makers. Therefore, the causal impact estimates from these two models show that the adopters of risk-reduction measures in wastewater-irrigated agriculture have a significant impact on consumption expenditure per capita and also crop income per capita. This paper provides new information on the reuse-oriented governance of urban wastewater in Sub-Saharan Africa. It also supports the emerging consensus that adoption of safer practices in wastewater-irrigated agriculture can enhance the welfare of many urban and peri-urban farmers in developing countries.

Acknowledgments

This research is financially supported by the Organisation for Social Science Research in Eastern and Southern Africa (OSSREA). All the participants who contributed their time in this study are also duly acknowledged.

References

- African Development Bank (ADB). 2010. *Nairobi River's rehabilitation and restoration programme: Sewerage improvement project*. Project appraisal report. Nairobi: African Development Bank Group.
- Ali, A. and Abdulai, A. 2010. The adoption of genetically modified cotton and poverty reduction in Pakistan. *Journal of Agricultural Economics*, 61(1): 175–192.
- Allen, N. and Ngonga, J. 2003. *Background paper on water and sanitation. Building Kenya together*. Conference on private sector participation in Kenya's infrastructure. Nairobi: Government of Kenya.
- Angrist, J. D. and Pischke, J. S. 2009. *Mostly harmless econometrics: An empiricist's Companion*. Princeton, NJ: Princeton University Press.
- Barcelo', D. and Petrovic, M. 2011. Waste water treatment and reuse in the Mediterranean Region. *The Handbook of Environmental Chemistry*. London: Springer.

- Becerril, J. and Abdulai, A. 2009. The impact of improved maize varieties on poverty in Mexico: A propensity score matching approach. *World Development*, 38 (7): 1024-1035.
- Blumenthal, U. J. and Peasey, A. 2002. *Critical review of epidemiological evidence of the health effects of wastewater and excreta use in agriculture*. Geneva: World Health Organization. Retrieved May 14, 2012, from: http://www.who.int/water_sanitation_health/wastewater/whocriticalrev.pdf
- C. A. Scott, L. Raschid-Sally, M. Redwood and A. Bahri. The International Water Management Institute and the International Development Research Centre. London: Earthscan.
- Caliendo, M. and Kopeinig, S. 2008. Some practical guidance for the implementation of propensity score matching. *Journal of Economic Surveys*, 22(1): 31–72.
- Cornish, G. A. and Kielen, N. C. 2004. Wastewater irrigation — hazard or lifeline? Empirical results from Nairobi, Kenya and Kumasi, Ghana. In *Wastewater use in irrigated agriculture: Confronting the livelihood and environmental realities*, edited by Scott, C. A., Faruqui, N. I. and Raschid-Sally, L. Wallingford, UK: CABI Publishing.
- Drechsel, P., Keraita, B., Amoah, P., Abaidoo, R., Raschid-Sally, L. and Bahri, A. 2008. Reducing health risks from wastewater use in urban and peri-urban Sub-Saharan Africa: Applying the 2006 WHO guidelines. *Water Science and Technology*, 57(9): 1461–1466.
- Dulo, S. O. 2008. Determination of some physico-chemical parameters of the Nairobi River, Kenya. *Journal of Applied Sciences and Environmental Management*, 12(1): 57-62.
- Ensink, J. H. J., van der Hoek, W., Matsuno, Y., Munir, S. and Aslam, M. R. 2003. *The use of untreated wastewater in peri-urban agriculture in Pakistan: Risks and opportunities*. Colombo: International Water Management Institute.
- Faruqui, N., Niang, S. and Redwood, M. 2004. Untreated wastewater reuse in market gardens: A case study of Dakar, Senegal. In *Wastewater use in irrigated agriculture: Confronting the livelihood and environmental realities*, edited by Scott, C. A., Faruqui, N. I. and Raschid-Sally, L. Wallingford, UK: CABI Publishing.
- Gathuru, P. K. and Nduati, J. K. 2001. *Taming food poverty or transforming the urban environment? The case of urban agriculture/sewage irrigation in urban centres, Kenya*. Paper presented at Workshop on Informal Peri-Urban Irrigation — Opportunities and Constraints, Kumasi, Ghana, March 7-9.
- Hammer Sr, M. J. and Hammer Jr, M. J. 2008. *Water and wastewater technology*. 6th ed. New Delhi: Prentice Hall.

- Hausman, J. A. 1978. Specification tests in econometrics. *Econometrica*, 46: 1251-1272.
- Heckman, J. 1979. Sample selection as a specification error. *Econometrica*, 47: 153-161.
- Heckman, J. and Navarro-Lozano, S. 2004. Using matching, instrumental variables and control functions to estimate economic choice models. *Review of Economics and Statistics*, 86(1): 30-57.
- Heckman, J., Ichimura, H., Smith, J. and Todd, P. 1998. Characterizing selection bias using experimental data. *Econometrica*, 66(5): 1017-1098.
- Hide, J. M., Kimani, J. and Thuo, J. K. 2001. *Informal irrigation in the peri-urban zone of Nairobi, Kenya. An analysis of farmer activity and productivity*. Report OD/TN.
- http://www.unep.org/roa/Nairobi_River_Basin/Downloads/Phaseii_publications/reports/PollutionMonitoringReportPhase2.pdf
- Jiménez, B. and Asano, T. 2008. Water reclamation and reuse around the world. In *Water reuse: an international survey of current practice, issues and needs*, edited by Jiménez, B. and Asano, T. London: IWA Publishing.
- Karanja, N., Mutua, G. K., Ayuke, F., Njenga, M., Prain, G. and Kimenju, J. 2010. Dynamics of soil nematodes and earthworms in urban vegetable irrigated with wastewater in the Nairobi River basin, Kenya. *Tropical and Subtropical Agroecosystems*, 12: 521-530.
- Kassie, M., Shiferaw, B. and Muricho, G. 2011. Agricultural technology, crop income, and poverty alleviation in Uganda. *World Development*, 39(10): 1784-1795.
- Keraita, B., Jiménez, B. and Drechsel, P. 2008. Extent and implications of agricultural reuse of untreated, partly treated and diluted wastewater in developing countries. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, 3(58): 1-15.
- Kilelu, C. 2004. *Wastewater irrigation and farmer's perception of health risks and institutional perspectives: A case study from Maili Saba, Nairobi*. CFP Report 38. Ottawa: IDRC.
- Lee, W. S. 2008. Propensity score matching and variations on the balancing test. Paper presented at the Third Conference on Policy Evaluation, ZEW, Mannheim, Germany, October 27-28..
- Lokshin, M. and Sajaia, Z. 2004. Maximum-likelihood estimation of endogenous switching regression models. *Stata Journal*, 4(3): 282-289.
- Maddala, G. S. 1983. *Limited dependent and qualitative variables in econometrics*. Cambridge: Cambridge University Press.

- Maddala, G. S. and Nelson, F. D. 1975. Switching regression models with exogenous and endogenous switching. Proceedings of the Business and Economic Statistics Section, American Statistical Association, 423-426.
- Mara, D. D. 2004. *Domestic wastewater treatment in developing countries*. London: Earthscan.
- National Coordinating Agency for Population and Development (NCAPD). 2010. State of Kenya Population 2009. Population dynamics and climate change: Implications for the realization of the MDGs and the goals of vision 2030. Nairobi: National Coordinating Agency for Population and Development.
- Obudho, R. A. and Kauti, M. K. 2002. *Urban and peri-urban agriculture in the city of Nairobi*. Regional Workshop on Urban Policy Implications of Enhancing Food Security in African Cities. Nairobi, Kenya, May 27-31.
- Patwardhan, A. D. 2008. *Industrial wastewater treatment*. New Delhi: Prentice Hall.
- Po, M., Kaercher, J. and Nancarrow, B. E. 2004. *Australian water conservation and reuse research program: Literature review of factors influencing public perceptions of water reuse*. Australian Water Association. April 2004, pp 1-27.
- Qadir, M., Wichelns, D., Raschid-Sally, L., Minhas, P. S., Drechsel, P., Bahri, A. and McCornick, P. 2007. Agricultural use of marginal-quality water opportunities and challenges. In *Water for food, water for life. a comprehensive assessment of water management in agriculture*, edited by D. Molden. London: Earthscan.
- Rosenbaum, P. R. 2002 *Observational studies*. 2nd ed. New York: Springer
- Rosenbaum, P. R. and Rubin, D. B. 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika*, 70(1): 41-55.
- Scott, C. A, Faruqui, N. I. and Raschid-Sally, L. 2004. Wastewater use in irrigated agriculture: Management challenges in developing countries. In *Wastewater use in irrigated agriculture: Confronting the livelihood and environmental realities*, edited by C. A. Scott, N. I. Faruqui and L. Raschid-Sally. Wallingford, UK: CABI Publishing.
- Tiongco, M. M., Narrod, C. A. and Bidwell, K. 2009. Risk analysis integrating livelihood and economic impacts of wastewater irrigation on health. In *Wastewater irrigation and health: Assessing and mitigating risk in low-income countries*, edited by P. Drechsel,
- United Nations Environment Programme (UNEP). 2003. *Nairobi River basin phase II: Pollution monitoring report*. Retrieved August 24, 2011, from
- van der Hoek, W., 2004. A framework for a global assessment of the extent of wastewater irrigation: The need for a common wastewater typology. In *Wastewater use in irrigated agriculture: Confronting the livelihood and*

environmental realities, edited by C. A. Scott, N. I. Farunqui and L. Raschid-Sally. Trowbridge: International Development Research Centre.

Willis, R. J. and Rosen, S. 1979. Education and self-selection. *Journal of Political Economics*, 87: S7-S36.

Wooldridge, J. M. 2005. *Instrumental estimation of the average treatment effect in the correlated random coefficient model*. Michigan: Michigan State University.

World Health Organization (WHO). 2006. *Guidelines for the safe use of wastewater, excreta and greywater. Volume 2: wastewater use in agriculture*. Geneva: World Health Organization.

River Based Agricultural Water Use Innovations in Uganda — Kabarole District: Opportunities and Challenges

Kirungi Jackline

Abstract: The paper is part of the overall efforts to examine the nexus between water and poverty in southern and eastern parts of Africa, with a case study of Uganda. Agricultural water use innovations remain to be seen as one area of great activity in improving efficiency and effectiveness of water, mainly in Africa. Nonetheless, activities are biased to drought prone areas and are largely based on trial and error. This paper limits its analysis to prospects of water use innovations in water resourceful areas. The paper argues that agricultural water use innovations in water resourceful areas are indispensable in the agricultural practices of rural communities in Uganda. The paper, however, observes that the tendency of successive environmental policies to take water as a stand-alone natural resource, has led to marginalization of river-based agricultural water use innovations in the district. Successive water governance regimes of rivers as natural resources need to envisage alternative water use techniques. Regulations that promote the closing off of farmers will have a detrimental impact on agricultural production in the district, which is a food crop hub in Uganda.

Keywords: Agriculture water use innovation, environment policy, natural water resources, subsistence farming, rural farmers, livelihoods

1. Introduction

Efficient and effective agricultural water use has of late become one of the cornerstones of debates in the era of climate change and development, in general. Every drop of water put to use, should be reflexive of the production it has sustained, in this case, in agriculture. This argument, however, is normally prioritized in drier regions of the country. This calls one to question the notion of effective and efficient water use in water resourceful areas, a gap that the paper sets out to examine, though limiting its focus on agricultural water use among rural farmers. The paper limits its analysis to agricultural activity along River Mpanga in Uganda and among rural farmers. The paper examines the following objectives:

- (a) To examine the institutional framework of agricultural water use innovations on rivers by rural farmers.

- (b) To analyze agricultural water use innovations among rural people, along River Mpanga.
- (c) To examine challenges and opportunities in agricultural water use in relation to agricultural practices of rural farmers.

1.1 Global Trajectory of Agricultural Water Use in Africa

At the global level, agriculture accounts for “70 per cent of all water withdrawn from rivers and aquifers” (UNCTAD 2011: 1). Nonetheless, Africa and Asia overshoot the average to 75 per cent and 60 per cent, respectively (Inocencio et al. 2003). In Africa, water withdrawal is, however, not commensurate to wellbeing. Water withdrawal, mainly from freshwater sources, is contrary to the low production and malnourished children (Inocencio et al. 2003). Limited water sources, however, are presumed to have a greater impact on rural farmers, the biggest contributors to Africa’s food crop production (UNCTAD 2011). Globally, a number of debates have been advanced in response to this controversy in Africa. Agricultural Water Management (AWM) in Africa has so far taken ground. The arguments advanced are pre-occupied with water use that is conscious of conservation of the environment. This has sparked suggestions of precision technologies, indigenous water use technology advancement (UNCTAD 2011) and sustainable agricultural intensification (IFAD 2011). Important in the responses, is the desire to minimize or control water use technologies that are detrimental to the environment in general. Most of the responses target rural farmers as these are the major food producers in Africa.

In addition, there has been a general debate to recount Africa’s policies on water and agriculture. What is at stake in Africa’s policies, in relation to water and agriculture? Policy questions largely point to the nexus between water, agriculture and the environment in general. Harvey (2008) argues that while most African countries Poverty Reduction Strategy Papers (PRSPs) are geared towards reduction of poverty, 75 per cent overlook water, for macroeconomic tenets such as liberalization, privatization and decentralization. Using network analysis models to understand the water network structure of two Nile Basin states — Egypt and Ethiopia — Luzi et al. (2008) also observed a high level of coordination among donor agencies and nongovernmental organizations (NGOs), of policy formulation and implementation, than compared to linkages between water consumers and polluters during the policy process in both countries. Policy initiatives on water have been more focused on marketing water and have excluded many rural farmers from regular water access. In Ghana, reports about “impressive water coverage” as of 2012, have meant that “46 per cent of households in Accra receive water, only ... rarely while 5 per cent never have sufficient water” (Obeng-Odoom 2012: 1140).

1.2 Environment, Water and Agriculture Nexus in Policy

Analyzing frameworks and tools for management of the environment in Africa, Nhamo and Inyang (2011) hail CIDA, DANIDA and World Bank, for including Africa-related concerns, such as poverty reduction, on their agenda though mentioned in passing. The agendas however neglect agriculture in their discourse. In the same line, African Development Bank Group's (2004) policy on environment, New Partnership for Africa's Development <NEPAD> (2002) and sub-regional environmental sustainability initiatives such as Regional Indicative Strategic Development Plan (RISDP), limit environmental concerns largely to the environment component and biophysical existence, and overlook agriculture, a significant sector for Africa's population. Nhamo and Inyang (2011) have equally observed that many of the environmental policies extended to Africa are largely oriented towards protecting natural resources rather than human beings. State of Environments Reporting (SoER) system for instance, demands reports on components of the environment to be read against the activities done by the people in the area of reporting. Nonetheless, the human nature nexus used in assessing environmental status is not streamlined in the environmental policy planning and implementation process.

At the international level environment policies have marginalized agriculture and successive environment policies at the national level, have restrained water use in agriculture. In 1999, the Republic of Uganda (RoU) issued regulations on water use in agriculture, no matter how it is accessed and used as a natural resource (water from rivers, lakes and canals) or as a commodity for commercial purposes in agricultural production. Nonetheless, successive water-related policies, and in particular environment policies, have issued more regulations that increasingly tighten governance of water. For instance, RoU (1995) passed the National Environment Act (NEA), which includes "limits" to use of rivers and lake as illustrated below.

Box 1: Limits to the use of lakes and rivers

- (1) Subject to subsection
- (2) no person shall, in relation to a river or lake carry out any of the following activities:
 - (a) Use, erect, reconstruct, place, alter, extend, remove or demolish any structure or part of any structure in, on, under or over the bed;
 - (b) Excavate, drill, tunnel or disturb the bed, otherwise;
 - (c) Introduce or plant any part of a plant, whether alien or indigenous, in a lake or river;
 - (d) Introduce any animal or microorganism, whether alien or indigenous, in any river or lake or on, in or under its bed;
 - (e) Deposit any substance in a lake or river or in, on or under its bed, if that substance would or is likely to have adverse effects on the environment;
 - (f) Divert or block any river from its normal course;
 - (g) Drain any lake or river.

(Adopted from National Environment Act, 1995).

The above limits are inclusive of all rivers and lakes in the country. The limits presume no activity on rivers and lakes, and presume that people living near these water sources have no relationship with them. In addition, the limits consolidate powers over rivers and lakes in the hands of government authorities. According to the act, no one, apart from the government's authorized agent, has the right to "declare protected zones along the banks of the rivers or lake shores within such limits it considers necessary to protect those rivers and lakes from deleterious human activities" (Section 53). In the act, the government withdraws all powers on lakes and rivers from the people near it. It has the authority to act as deemed fit. The Government of Uganda, in this case, is silent on any activities related to water use in agriculture. RoU (1999) emphasized grassroot-based policy planning and implementation. Grassroot associations such as User Association Groups (UAGs), Community Based Maintenance Systems (CBMs) and Water Resource Committees (WSC), were given prominence for any water policy planning and implementation processes. The committees were to act as instruments through which collective decisions on water as a resource, whether in agriculture or for other purposes, were to be deliberated. The NEA overtook the powers of community-based bodies.

Successive environment policies have tightened governance of environment components, among which are natural water resources. For instance, RoU in 1999, allowed subsistence farmers the opportunity to access water without a government license, and large-scale water users were to apply for a permit for water abstraction. In 2007, the opportunity was stripped (Ministry of Local Government <MoLG> 2007). Like in the NEA, the ministry reserved all powers to authorize any farming practices in Uganda, under the categories of livestock and range management, crop husbandry, water supply, piggery, fisheries, bee-keeping, and rabbit keeping on natural water resources. The policy is all inclusive of subsistence and large-scale farmers. It reserves all powers to “identify and determine potential environmental impacts ... possible mitigation measures ... on all projects ... regardless of the source of funds” (Environmental Checklist for Sub-county/Division/Town Council Local Governments Number 1, MoLG 2007). The government rests all the power to approve all types of farming projects in the District Technical Project Committee (DTPC) and District Agricultural Officer (DAO). It should be observed that environment policies are sensitive to farming, in policy. The policies, nonetheless, act to constrain agriculture activities to the benefit of the environment, which includes natural water resources. In addition, are the Water Management Zones (WMZ) and Catchment Management Organizations (CMO). These organizations target water catchment areas of rivers that flow into the Nile, among which are rivers Mpanga, Mubuku, Rwizi, and Semliki. The organizations also consolidate power over water catchment areas in the local government as a key player in environment and natural resources activities (Ministry of Water and Environment Sector Report 2011). Successive environment policies have increasingly tightened use of rivers in relation to agriculture.

In the agricultural sector, policy is sensitive of the interdependence of agriculture and water, given the fact that Uganda’s rainfall pattern is unreliable with unevenly spread water resources. The relationship has however been insubstantial. As of 1999, a directorate responsible for irrigation in the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) was envisaged. The directorate was to be in-charge of planning, advising, supervising, and monitoring the management and use of irrigation and livestock schemes (RoU 1999). However, as of 2010, the government hardly had anything to report regarding water for production (RoU 2010). The latter situation has been attributed to the government’s lack of a conceptual, operational and maintenance framework, for water for production, and to a limited extent, financial challenges.

In the National Development Plan (NDP) 2010/11-2014/15, the government advances a plan for water production (RoU 2010). The objectives include (i) To increase acreage under irrigation; (ii) to increase supply of water in the cattle corridor, from the current 36 per cent to 50 per cent, and those outside the cattle corridor from 21 per cent to 30 per cent; (iii) To strengthen management of water catchment areas around water

sources for production facilities; (iv) To increase water supply systems for rural industries, to facilitate agro-processing and other industrial activities; (v) To increase water supply for multi-purpose use in water stressed areas of the country. The plan is, however, biased towards equipment development in the hands of the private sector rather than indigenous farmers.

There is no objective geared towards the development of the framework of operation of the irrigation scheme in the country. Moreover this is noted as the biggest challenge to water for production. The government, for instance, proposes to build five new large irrigation schemes, 50 micro-level model irrigation schemes, 150 valley tanks, and develop appropriate technology for household-level irrigation. The government prioritizes private sector partnerships in the development of equipment for irrigation. Strategy 4 under objective 1 and Strategy 3 under objective 2, plan to train private sector players as a mechanism through which to extend the water for production interventions. The private sector is to be trained to provide operational and maintenance services to farmers. Sixty private sector players are to be trained for irrigation schemes and 150 for the water dams. Private sector players are a priority in the development of water for agricultural production.

So far, activity on agricultural water use has taken a different trend, and is largely in the hands of the private sector. Initiatives responsive to water management in general, are biased to dry areas. Of the many prompts to innovations in Uganda, only Pico-Hydro Power was tried out in water resourceful areas but only in those with enough flow and height over which the water falls, to install hydropower. Only 5.4 per cent of the innovations already in place are disseminated to business and community at large, as 94.7 per cent remain known only to the technical team (Innovations Systems and Clusters Program-Uganda 2011). Government action on water use in agriculture is limited to the “driest regions of the country; limiting efforts on agriculture water use innovations in the dry water corridor of Karamoja, Western and Eastern Uganda” (Ministry of Finance, Planning and Economic Development 2008: 6). Uganda’s adaptability to irrigation is just 1 per cent, accounting for 14,418 hectares under formal irrigation and 67,000 hectares under informal irrigation, out of an estimated 202,000 hectares of irrigable land (MAAIF 2010). Water use innovation in agriculture remains limited, in general, in the country.

Meanwhile, the poor state of agricultural water use innovations in Uganda exists alongside low agricultural produce in the country, not to mention general decried poor agricultural produce in Africa (Benin et al. 2012). Poor agricultural produce in the continent has provoked a general call to increase budgetary allocation to the agricultural sector, through the Maputo Declaration on the Comprehensive Africa Agriculture Development Programme (CAADP). In the Ugandan case, the situation is a bit more complex. Despite the increase in the number of persons engaged in

agriculture, from 65.5 per cent in 2001/03 to 73.3 per cent in 2005/06, 70 per cent of the people in the sector are below the poverty line. This is coupled with a decline in agricultural gross domestic product (GDP) from 33.1 per cent in 1997 to 15.4 per cent as of 2008 (Ministry of Finance, Planning and Economic Development 2008).

Investment in agriculture generally has remained unproductive, though the government insists that “official development assistance (ODA) towards the agricultural budget in Uganda is large” (Ministry of Finance, Planning and Economic Development 2008: 28). Most farmers have been left to subsist on micro-finance institutions created under the credit scheme and rural development strategy, so far in 970 sub-counties. The National Agricultural Advisory Services (NAADS) is one of the most widespread programmes in the country, extending to 80 districts, as of 2009. The programme has had to cope with numerous institutional and financial challenges. In addition, NAADS’ agricultural investments have been noted as “field trials [that cannot] achieve or sustain high yields ... achieve comprehensive technology adoption rates” (Benin et al. 2012: 295). There is need to envisage the way forward for increased agricultural production. What possibilities exist along rivers in Kabarole District as one of the water resourceful areas in Uganda?

Figure 1 presents a conceptual framework with links that are significant in understanding the process that triggers off productive engagement with a people’s natural resources. The conceptual framework was sensitive of the process of change in property rights and technology (equipment and technique of water use). This study, however, presumed the technologies and rights as pre-existing, but under the willpower of the farmer — agent. It is noteworthy that the paper examines the relevance of river-based water use innovations.

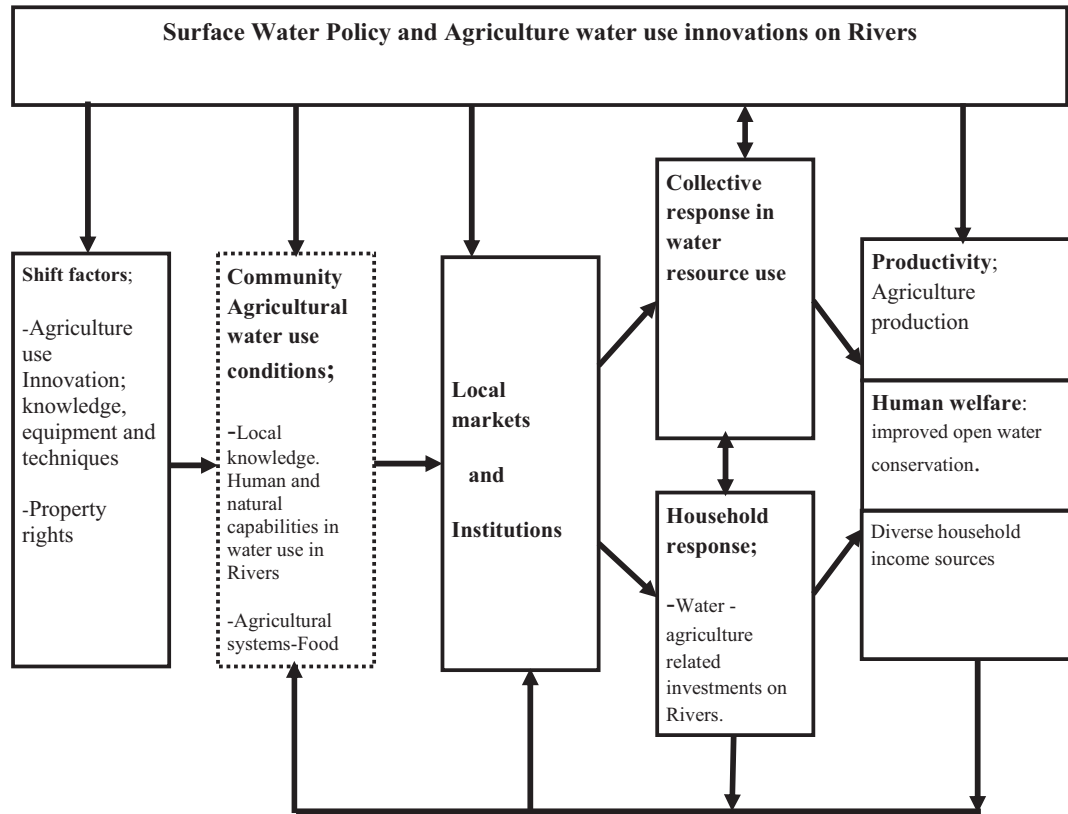


Figure 1: Conceptual Framework

(Adopted from Scherr et al. 1996 in Scherr, S. <2000>).

Water use innovations in this case were understood to refer to techniques and equipment used by rural farmers to access water from rivers, for their agricultural activities. The conceptual framework notes that farmers' capability (to make use of the river) is largely dependent on the proximity to the water source (river). The river is understood as flowing through the farmer's lands. The river, in this case, was understood as a point of water collection, which ensures constant water flow and thus enables a farmer to imagine provisions to make use of the water in their respective agricultural activity. Market accessibility, income generation and policy setting were conceptualized as triggers within which the farmer begins to imagine the process to access, develop and utilize the river, to enhance agricultural productivity.

2. Research Methodology

2.1 Study Area

The study was limited to Kabarole District in Burahya County and in Bukuuku sub-county, in Western Uganda. The district is bordered by Kasese District to the south, Kamwenge in the southeast, Kyenjojo in the east, Budibugyo in the northeast, and Kibale in the northeast. Kabarole lies between 0 degrees 15'' N and 1degree 00N latitudes and 30 degrees 00'' E31 degree 15'' E longitudes. The district is composed of two counties: Burahya and Bukuuku. Burahya County, in which this research was based, has the highest population comprising 53 per cent of 403,200 people in Kabarole District. The district has a total area of 1,841 square kilometers, of which 198 square kilometres is covered by open water and wetlands, 1,569 square kilometres is covered by arable land, while the area under cultivation is 1,307 square kilometres. The district has a ragged mountainous relief (Rwenzori) and undulating rolling slopes towards the lowlands. It is covered by black loam soils over red, sandy clay loams (volcanic soils). The district has good climate with fairly evenly distributed rainfall throughout the year. Temperatures range between 20°C degrees centigrade to 25°C in most parts of the district. Livelihood activities include subsistence farming, which accounts for 77 per cent of the district's day-to-day survival activities. The district has a bimodal annual rainfall ranging from 1,200-1,500 millimetres. It lies at an altitude of 1,300-3,800 metres above sea level (Kabarole District Local Government 2007). The district has 32 rural areas and 3 urban areas. It shares the Rwenzori Mountains ecosystem, which is one of the largest and most significant water catchment areas in Uganda, which contains the major source of the White Nile that flows through River Semuliki into Lake Albert. River Mpanga is one of the rivers that flow through the district, in addition to rivers Mahoma, Rwimi and Sebwe (Ministry of Tourism, Trade and Industry 2006).

2.2 Data Collection

The study was conducted in two intervals — February and September 2012. It was a wholly qualitative study, given the exploratory take on the concept of water use innovations among subsistence farmers, in policy documents and in the district local government structure. The main method of data collection was through interviews, observation, focus group discussions, and document review. Interviews were conducted using an interview guide. Interviews were used to obtain information from district and lower local government officials in the Bukuuku Sub-County. Bukuuku Sub-County was purposively selected as the sub-county in which River Mpanga shared a boundary with most of the farmlands. The officials were sampled using snowball sampling technique, leading to a sample size of 33 respondents: 19 females and 14 males. Using the latter sampling method, the researcher interviewed senior district officials in three departments: Natural Resources Department, National Agricultural Advisory Programme, and Production

and Marketing Department, as they were the points of reference in the district, in regard to river-based agricultural water use innovations. In the lower local government, selection of officials also followed snowball sampling method.

In the community, three focus group discussions were conducted in Bukuuku Sub-County. Key informant interviews in the community were limited to farmers who happened to be in the gardens at the time of research. Observations were made along the river on farming types in place. Document review was limited to policies that contained regulations that had an effect on river-based agricultural water use and water for production on open surface natural water resources in Uganda. At the national level, policies reviewed were mainly national cardinal policies in regard to water for production, and on rivers. These included the National Development Plan 2010/11-2014/15, National Water Policy 1999, National Environment Act 1995, and the Agriculture Sector Development Strategy and Investment Plan 2010/11-2014/15. In addition, district local government policies found in district departments, used to regulate open water sources, were reviewed.

2.3 Data Analysis

Data analysis was by content analysis of field data and text analysis of policy documents guided by the conceptual framework adopted by Scherr (2000), from Scherr et al. 1996. The framework underlines farmers as active constituents in the fulfillment of environment and poverty reduction policy objectives. The presumption led to themes that were sensitive to the intersection between farmers' point-of-view and possibilities, opportunities, and challenges in river-based agricultural water use innovations. Farmers' experiences in the use of equipment, water management techniques, and new planting varieties, emerged as significant templates, through which to understand the prospects of river-based agricultural water use innovations in Kabarole District, a water resourceful area. In the field, it was noted that agricultural district technical officials were quite dependent on farmers' experiences as the basic formula through which to validate the state of art, of agricultural water use innovations on River Mpanga. Farmers' perspectives, therefore, were a key template through which to understand water use innovations in rural farming, in the area of study. Government policies that regulate river-based agricultural water use were drawn, to understand the possibility of water use innovations on River Mpanga, in the district.

3. Results and Discussions

3.1 Mapping the Institutional Framework for River Based Agricultural Water Use Innovations in Kabarole District

It was observed that structures to deal with water use innovations along rivers were in place, in the district, namely the production and marketing department representing MAAIF, the district environment and natural resources department, office of the secretary for production and natural resources, and NGOs. In addition, sub-county level and local-level regulatory structures were in place. At the time of research, it was noted that the sub-county chief, community development office, water user groups, water and sanitation committees and individuals (farmers), were operating at the lower local level. All these structures were as was proposed in the National Water Policy of 1999. Research findings revealed that none of the district local government departments entitled to initiate and plan river-based agricultural water use innovation had any initiative in place, so far. The few initiatives on agricultural water use innovations along River Mpanga were noted, a concern for NGOs and at propositional level.

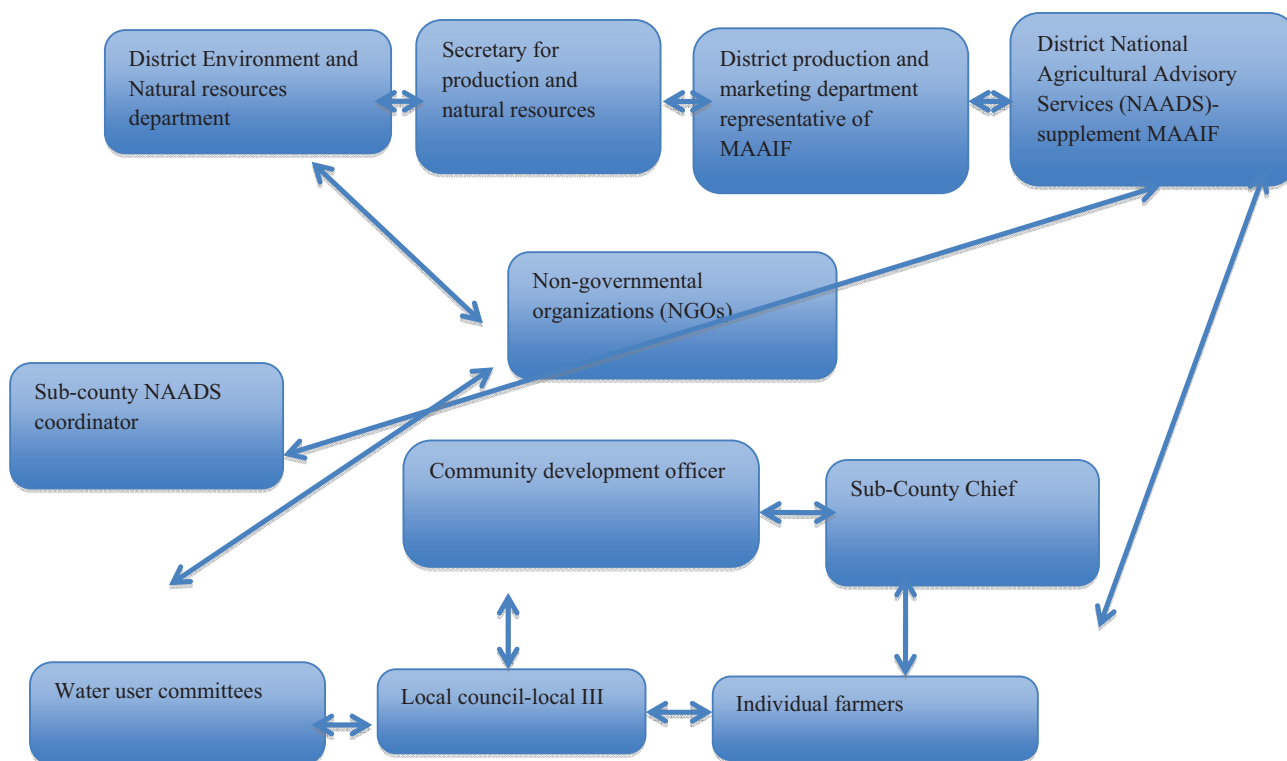


Figure 2. Structure of water use management on rivers in Kabarole District(Adopted from Natural Resources Department Report, April 2012, Kabarole District).

According to the research findings, the district environment and natural resources department were well connected with the rest of the lower local structures, except for environmental concerns, than river-based agricultural water use innovations. The district environment and natural resources offices oversee general activity in the district. The lower local government structures are the department's focal centres in the community. The district production and marketing department, a representative of the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), and the district National Agricultural Advisory Services programme (NAADS), interact only among themselves and the individual farmers. Environmental concerns are prioritized and well grounded, more than agriculture activities.

The Environment and Natural Resources Department (ENRD) was the most pointed at, with regards to issues on rivers. Nonetheless, the department did not have any river-based agricultural water use innovations. Its activities were more inclined to drawing parameters that govern the relationship between farming and surface waters (wetlands and rivers) in the district. The department, for instance, did physical monitoring of wetlands and rivers, and issued warnings (verbal and written) to farmers who had encroached on wetlands and riverbeds, or those who had contaminated river waters. Table 1 shows activities of the ENRD.

Table 1. Activities of the Environment and Natural Resources Department, Third Quarter, Financial Year 2009/2010-Kabarole District

Type and Location of natural resource	Conservation	Who brought about the changes	Action taken/Recommendation
1 Kiyaga Wetland Hakibaale Sub-County	Degraded	Reclaimed for cultivation and grazing by Kyomuhendo Daniel, Byamukama Paul, Twesigomu Godfrey, Rwaheru Jacob, Mayindo Francis	Environment improvement notices were issues to the encroachers.
2 Buheesi Wetland, Karambi Sub-County	Degraded	Reclaimed for cultivation and grazing by Mr. Charles Kamurasi	Environment improvement notices were issues to the encroachers
3 Kyaninga Hills in Kibiito Sub-county	Degraded	Deforestation and poor methods of farming which have left the hill prone to erosion and heavy winds.	Following the onsite meeting with the affected residents, the district planning to plant trees on the hills in the month of May 2012. The trees will be donated by Kyaninga lodge.
4 Mucwakwanzi Wetland,	Degraded	Reclaimed for cultivation and grazing	Following issuance of environment improvement

	Bukuuku Sub-County		by Love Robert, Nyakairu and Chris Nyarubona	notices some parts of the wetland are undergoing natural regeneration
5	Mpinga and Mitomi wetlands in Kicwamba sub-county	Degraded	Reclaimed for cultivation and grazing by Kwame investments, Family of the Late Kaijuka and Mugenyi	Environment improvement notices were issues to the encroachers
6	Njuguta Wetland in Ruteete Sub-County	Degraded	Eucalyptus woodlots and grazing by Mwesige, Patrick, Kaihura Isaac and Sanyu of Kiko	Some improvement noted compared to the previous inspection.
7	River Mpanga Bank in Bukuuku Sub-County	Degraded	By stone and sand miners	On spot sensitization meeting and miners agreed to plant trees
8	Butebe Local Forest Reserve	Re-opening of boundary for Butebe forest reserve	Report yet to be produced by the district surveyor.	

Source: Adopted from Natural Resources Department Report, April 2012, Kabarole District.

In the report there is hardly any remark on river-based agricultural water use. Reports on River Mpanga note that the activities of sand and stone miners have damaged the river in Bukuuku Sub-County, while grazing and cultivation were the main activities through which wetlands were degraded in the district. In the report, the department was more concerned with mapping bad practices and not agricultural water use innovations or good practices. The department is seen as more inclined to establishing causal relations between nature and human activities, a condition set by the State of Environment Reporting System <SoER> (Nhamo and Inyang 2011).

At the district level, the ENRD is the focal point for NEMA. In this regard, the department in collaboration with the production and marketing department, was allowed to guide, and where possible, introduce river-based agricultural water use innovations as deemed necessary, depending on its environmental impact assessment (RoU 1999). The ENRD, like NEMA in sub-section 6.4.6, under the “Environmental and Public Health Aspects” (28), has the flexibility to:

- Develop water for agricultural production but subject to environmental impact assessment;
- Promote proper livestock watering methods;
- Promote water resources and proper watershed management.

In the same section, the policy demands that irrigation users should prevent an increase in salinity levels in the receiving waters, and accumulation of dangerous or toxic compounds in the subsoil, capable of contaminating underground waters. But according to research findings, the department had no initiatives in place.

Instead, the ENRD compiled and produced district environment reports haphazardly. The department had not done a scientific environment and natural resources report for the previous ten years (Interview, September 2012). The department attributed this to poor resource funds allotted to the department. However, it expected to offer guidance on river-based agricultural water use development as per its mandate but it was hardly in a position to do so at the time of the research, as noted in the quote below.

The National Environment reports are truly speaking fake. People come to me and I just tell them off my mouth, what is at stake. But it's hard to ascertain the accurate data. To be saying the right, for example, cubic centimeters of water, you should have been able to detect the water amount regularly. But this national environment management authority does not do so. It just wants to hear from me, than facilitate a scientific process to come up with the rightful figures (Interview, September 2013).

The marketing and production department at the district represents the MAAIF. In the National Water Policy (1999), the ministry like its department, are mandated to establish demonstration farms and train users in better agricultural methods, management and protection of water resources and the ecosystem. All these point to possibilities of initiating river-based agricultural water use innovations, which were hardly in place at the time of research.

In 2000, the Government of Uganda introduced the Plan for Modernization of Agriculture (PMA), inclusive of which is the famous National Agricultural Advisory Services (NAADS) programme, meant to complement MAAIF's role (MAAIF 2010). In this regard, the role of MAAIF and its down-line department, like the marketing and production department at the district, is to oversee the implementation of the NAADS programme. Talking to the officers in both departments (production and marketing department, and NAADS), whose major clients are farmers, it was observed that there were hardly any river-based agricultural water use innovations in both departments.

There had been earlier attempts to introduce treadle pumps as river-based agricultural water use innovations but these registered no success. In 2005, an organization known as Area Based Agriculture Programme, in collaboration with the Production and Marketing Department, introduced treadle pumps on River Rwimi but due to complaints of drudgery, raised by farmers in relation to operation of the treadle pump, the technology was rejected. According to the officer interviewed, the equipment was bound to

take off, should there have been time and commitment to encourage farmers to appreciate the usefulness of the technology (Interview, February 2012). Nevertheless, both officers could not avoid commenting on the poor water use mechanisms by farmers along River Mpanga, and rivers in general, as was noted below.

Farmers have encroached on the riverbed and planted small plots of different types of horticulture crops. This has widened the riverbed. Rivers provide water to grow horticulture crops like tomatoes, cabbages, onions, cornflower and garlic in the areas. I know of individuals who planted these crops in a crude way, instead of irrigation. The 50 metres requirement away from the river is not adhered to (Interview, September, 2012).

There was need for river-based agricultural water use innovations in the district, as failure to introduce such innovations has not prevented using of the river waters for agricultural activity.

The Secretary for Production and Natural Resources, in the district, represented the ENRD in the council. In an interview with the officer, poor agricultural water use mechanisms were reported along River Mpanga and were presumed to be the cause of floods that had taken place in the area, at the time of research. Either way, the officer was not able give any account of river-based agricultural water use innovation or initiatives on the river. The office of the Secretary for Production and Natural Resources is more of a political office than a technical office. It helps to deliberate on environment and natural resources in the district council.

At the sub-county and local levels, all the structures in place were equally charged with environment component monitoring. Like the district structures, there were no river-based agricultural water use innovations at the sub-county level and lower local government level, in the district. The sub-county chief and community development officer acted as environmental focal persons, at the lower local government level. They monitored the management of the environment and natural resources use. Water use committees are also charged with reporting and intervening where possible, such as in the case of complaints of water contamination by people, mainly rearing pigs along the rivers, or attempts to divert the river due to fear of floods.

In the National Water Policy (1999) the government envisaged working with NGOs to implement the strategies set out in the water policy. NGOs were in operation in Kabarole District. Apart from Protos-Uganda, most NGOs were not involved in river-based agricultural water use innovations. In the case of Protos-Uganda, river-based water use innovations took the form of food crops and fish species that would grow in wetlands and in rivers. Its innovations envisaged pragmatic action that would balance environment sustainability with agricultural livelihoods of the people in the area. Crop varieties, for instance, not only promised food but also limited

disruption of the ecosystem. However, these initiatives were at planning level and yet to be implemented. Protos anticipated supplying coffee, mudfish and mangoes to people living near wetlands through which River Mpanga flowed. The NGO reached the latter compromise after the organization had registered no success in places where campaigns to conserve the river did not offer an alternative means of survival.

Although the policy recognized individuals as part of the organizational structure in implementation of water policies, it did not define their roles. In this research, individuals were taken to be farmers living along River Mpanga, who have improvised river-based agricultural water use innovations. Indeed, like the policy had forethought, farmers are partners in the management of rivers. Farmers had introduced river-based agricultural water use innovations, mainly jerricans, saucepans and basins, to withdraw water from the river to increase their agricultural production. Farmers have also planted water resistant varieties, such as sugarcane and pasture grass as well as trees, along the banks of the river. River-based agricultural water use innovations along River Mpanga, were mainly in the realm of farmers.

Mapping the structure and institutional framework for river-based agricultural water use innovations, it was observed that the structures and institutions to enable these innovations, were in place. What was missing was the implementation of river-based agricultural water use innovations, which resounds with observations of the National Development Plan 2010/11-2014/15. River-based agricultural water use innovations in Uganda were emphasized in the National Water Policy (1999) and in the Agriculture Sector Development Strategy and Investment Plan, 2010/11-2014/15 (MAAIF, 2010). However, the propositions are yet to be implemented. Institutions and structures in the district are more inclined towards implementation of environment-related activities.

Research findings have, however, revealed that water for production and, therefore, water use innovations in form of equipment and water management techniques along River Mpanga, are equally important. Farmers need the equipment and water conservation technology to ensure all-year round crop production, maximize water utility and mitigate water calamities. Farmers also need equipment and awareness raising on better farming and water use practices, to control intoxication of the river. Water for production technology in water-endowed areas, has to be modified to serve withdrawal purposes and prevent intoxication of water sources as will be elaborated below.

3.2 Agricultural Water Use Innovations along River Mpanga

Agricultural water use equipment and water management techniques were not a new phenomenon in farming, in the area of study. The findings resound claims that have observed that just like green water, blue water is equally important for agriculture (United Nations Conference on Trade and Development (UNCTAD) 2011). Farmers regularly withdraw water from

the river for use in their agricultural activities. Water in this case was not to be stored but withdrawn and used whenever needed. Water was seen as a given, but had to be taken out of the river and transported to the garden. The innovations noted were in two forms: (i) Farmers' basic equipment, which they used to withdraw water from the river purposely to enhance agricultural production; (ii) Techniques to manage the water in rivers so as to ensure a sustainable and conducive environment for agricultural production.

The first form of innovations includes equipment such as jerricans, saucepans, perforated plastic containers, and watering cans, used by farmers to withdraw water from the river and transport to their gardens. The jerrican was the main type of equipment purposely used to withdraw water from the river and transport to the garden for use. This was revealed by farmers' focus group discussions in Bukuuku Sub-County as noted below.

Box 2: Focus Group Discussions (FGD)

We get the water from the river using jerricans. You cannot construct a trench or channel so that you access the water. You have no pump, so that you pump the water. We carry in the jerrican, water that we use to mix pesticides. Like one jerrican to spray weeds (Male respondent, FGD 1, September 2012).

It is only labour challenges. It is tiresome to carry jerricans from the river to the garden (Male Respondent, September, 2012).

They fetch the water in jerricans. Others use saucepans (all laughed – Hahaha). Whether dirty or clean, they do not mind. Others use buckets. Those washing near the river use their basin to withdraw water from the river (Female respondent, FGD 2, September, 2012).

Some people use saucepans and basins but such a person the river is just near by the garden. It also depends on the cabbages you have. You bring a lot of water. You keep going back to the river to refill the jerrican when the water gets finished (Female respondent, FGD 3, September, 2012).

(Author's fieldwork).

Jerricans, as observed in the FGDs, were reported as the main equipment that farmers have improvised to withdraw and use water from River Mpanga in their agricultural activities. The jerricans observed ranged from 5-20 litre water carrying capacity. Other equipment reported and used to withdraw water included saucepans and buckets. Figure 3 shows a man with jerricans.



Figure 3: A Man with Jerricans after Withdrawing Water from River Mpanga

(Adopted from author's fieldwork).

In this study, jerricans, saucepans and buckets are referred to as primary river-based agricultural water use innovations. This is the equipment that assists farmers to get in contact with the river and withdraw water, right from the river to the garden. This equipment is not meant to store water but to facilitate transportation of water by the farmer, from the river to the garden, where it is to put to use.

Also noted was secondary river-based agricultural water use equipment that helps farmers to put water from the rivers to use. This equipment was used to hold water for use in the farm or in the gardens. The equipment facilitates the process of mixing pesticides with the appropriate amount of water so that it can be sprayed onto crops or animals such as cows. Other equipment is used to hold water to irrigate the vegetables. One type of equipment observed had a carrying capacity of one liter. This was a perforated plastic container used to spray pesticides on cabbages and sometimes used in water irrigation as shown in Figure 4.



Figure 4: Perforated Plastic Container for Spraying and Irrigation of Cabbages along River Mpanga

(Author's fieldwork).

Also noted was a water trough with a carrying capacity of approximately 20 liters. The trough was observed about 3 metres away from the riverbank. In an interview with one of the women grazing cattle, it was reported that the trough was used to collect water, rather than *store water* (author's emphasis) for the cattle to drink. Nonetheless, in the FGD it was also noted that some farmers bring their cattle directly to the river, to drink from it (FGD 2, September, 2012). Other secondary river-based agricultural water use equipment was a watering and spraying pump, mainly used to spray pesticides on crops and cattle. The equipment is not meant to store water but to hold the water and use it for the immediate need. To what extent does the equipment prevent intoxication of the river stream? The question could not be answered by this research as it requires more rigorous scientific and quantitative fieldwork.

Withdrawal of water from River Mpanga for agriculture falls under three main arrangements, namely water for irrigation during the sunny season, water for mixing pesticides to spray crops and animals, and water for livestock to drink. Water for mixing pesticides to spray animals and livestock was withdrawn from the river on a regular basis. Water for irrigation of vegetables was withdrawn mostly in the sunny season.

In the sunny season farmers use it to spray water on their crops
(Female respondent, FGD 3, September, 2012).

We use it to spray crops with water and pesticides. In some seasons, the sun is strong and so we use the water to irrigate our gardens like tomatoes, cabbages (Male respondent, FGD 2, September, 2012).

In relation to the above, it was revealed that farming in the sunny season was a more lucrative venture than farming in the rainy season. The argument was fronted in one of the FGDs. A follow-up on the challenge raised in some of the interviews, in relation to the mismatch between agricultural turnovers and investment in river-based agricultural water use innovations, revealed that well-timed farming, which includes farming in the sunny season, was one of the solutions to the challenge.

The challenge of agricultural turnovers failing to match investment is seasonal. In the rainy season cabbages, for example are priced low and in the sunny season, the prices are high. A sack of cabbages in the rainy season can be bought at 5,000 shillings (USD 2). In a good season [a season in which supply of cabbages is limited and demand on the market is high], a sack is bought at 60,000 shillings (USD 24). But we who border the riverbanks are able to sustain gardens all through the year (Male respondent FGD 1, September 2012)).

Even if you do not irrigate your crops the dew is enough for your crops to give yield. Especially in Bukuuku Sub-County you will find most of the foods varieties all the time. If God took Mpanga away from us we would die (Female respondent, FGD 1, September, 2013).

River-based agricultural water use equipment, in this case, is relevant in two aspects. It allows the farmer to overcome seasonal farming limitations and increases agricultural turnovers. Seasonal farming in the area is not only due to unreliable rainfall patterns but also unpredictable agricultural turnovers. River-based agricultural water use equipment offers farmers an opportunity to partially overcome the challenges of unreliable rainfall and unpredictable agricultural turnovers. Unpredictable agricultural turnovers were another cause of seasonal farming and a pointer to unstable food supply.

River-based agricultural water use equipment was also employed mainly on small plots of land. Crops grown on these plots included cabbages, tomatoes, onions, green paper, bitter plants, eggplants, and Irish potatoes. In most of the focus group discussions, approximations made in regard to the size of the plot onto which the equipment was put to use ranged from $\frac{1}{4}$ to $\frac{1}{2}$ an acre. The size of the gardens was, however, attributed to limited land in the area as noted below.

We are not large-scale farmers but we have a good place. Traders from Kampala (capital city) will always find *matooke* in this place. We do not have big lands (Male respondent, FGD 1, September, 2012).

No. Here we no longer have big gardens because our lands are small. If it is very big, it's a $\frac{1}{4}$ an acre. We live on small lands. Most of the gardens are almost equal to one's home compound ($\frac{1}{4}$ an acre). We have produced children, and their children have produced others. You find that a parent divides land among his or her children. The children produce other children they to divide their small portions among their offspring and others even end up not getting land. There are also those who do not know the importance of land and have sold it to the rich. For me I see two things that contain riches: Land and education. But those who do not know the use of land they have sold it (Female respondent, FGD 2, September, 2012).

According to field findings, scarcity of land in Bukuuku Sub-County was due to increased population in the area. However, it should be noted that banana plantains, one of the major food crops in area, occupied the biggest land acreage, ranging from one acre to four acres, depending on the amount of land that a family occupied. Bananas are food crops but are also sold to earn income. Livestock farming was also on small-scale, two to twelve cows per family. These findings resound with claims that subsistence farming accounts for 77 per cent of day-to-day activities in Kabarole District (Ministry of Trade and Industry 2006).

The district, nonetheless, remains one of the districts in Uganda that greatly contributes to the food crop market (Chronic Food Insecurity Evidence-Based Analysis 2011). According to one of the agricultural officers, the district runs six markets a week. "We have daily area markets: Rubona market on Monday, Karago on Tuesday, Mugusu on Wednesday, Kasuganyaja on Thursday, Rwimi on Friday, and Kisomoro on Saturday. You find several lorries of *matooke* [banana] heading to Kampala [capital city of Uganda]" (Interview, September, 2013). The findings resound with claims by UNCTAD (2011) that hail smallholder farmers (small farms of less than 1 hectare in size) as the backbone of African agricultural produce. Banana plantations are not irrigated. Water to sustain banana yields was noted as being sourced from rain and groundwater (FGD 1 and FGD 3, September 2012). Vegetable gardens on which river-based equipment was put to use, supplement income and food in the area. They have short growing periods and are marketable.

In the second category of river-based agricultural water use innovations were vegetation and trees planted on the bank of the river. In this case, farmers had improvised mechanisms to mitigate calamities that they anticipated from the river. Initiatives in this category included plants along the banks of the river that served as vegetation cover and pasture. The plants are intended to hold the soil firm so that it is not washed away by water. This would enable the farmers to make use of the water resource and avoid negative outcomes in their agricultural activities.

The above category of river-based water use agricultural innovations was noted as compulsory, at least for all farmers in the lowland areas through

which the river crossed, especially if one's land shared a boundary with the river. The plants in this category included sugarcane, plantains, trees, and vegetation, which doubled as pasture for the cattle. These were meant to reduce the washing away of the riverbank and reduce the chances of the river over-flowing and washing away their gardens, and at worst, their land (Interview, September, 2012). Some of these plants were edible such as sugarcane and cassava.



Figure 5: Vegetation and Cassava Along Banks of River Mpanga
(Author's fieldwork).



Figure 6: Vegetation Along River Mpanga
(Author's fieldwork)

Scherr (2000) has equally observed that resource-conserving technologies adopted by poor farmers are those that contribute to increased productivity or output stability and are economically viable, in the farmer's context of risk and resource constraint. Likewise, farmers along River Mpanga were aware of the usefulness of the water in the river running through their gardens. They were aware of the water calamities that are likely to befall them as a result of their nearness to the river. Therefore, farmers sustained vegetation cover along the river, which controls the effects of the water in case it floods. The farmers also sustained some agricultural activity along the river.

3.3 On Farmers: Water Use Innovations in Agriculture in Kabarole District

In the field, questions on agricultural water use equipment and knowledge evoked expressions of experiences so far encountered by agricultural officers, in relation to the animal and seed varieties that were introduced to farmers at the time. A leaf can be drawn from the experiences encountered, in the process of introduction and adoption of new crop varieties. The experiences were used by a number of agricultural officers to substantiate their standpoint on the status of water use innovations along River Mpanga in the district.

Agricultural officers observed agricultural turnovers as a significant factor in agricultural innovations, a case that was illustrated by farmers' rapid adoption of high-yielding rice variety introduced in the district.

We [marketing and production department] introduced rice in Rwimi to 5 [five] people. Over 500 [five hundred] today have adopted rice growing in Rwimi. This has been a result of farmers seeing the economic benefit out of this rice growing (September, 2013, senior district agricultural officer).

The above success, according to the production and marketing officer, was attributed to the fact that the "people ... realized the economic benefit" and adopted the rice. The latter upholds earlier observations by the NAADS coordinator that "This type of rice yields 50 kilogrammes for every kilogramme sowed." This implied that the benefits from the type of rice were more than expected. It should, however, be noted that rice involves a lot of drudgery: scaring away birds from the crop, planting, harvesting, and sorting. Farmers, however, counterbalance the latter with 50 kilogrammes of rice for every kilogramme sowed.

The seed and animal variety experiences also revealed that there were disagreements and struggles among agricultural experts and farmers, in regard to authority over innovations development in agriculture. Taking the example of one of the officers in the district, it was argued:

Farmers decide what they want under NAADS and yet they do not have the knowledge about the technologies. Instead they concentrate on traditional farming methods. I [agricultural officer]

know what one can grow here given the type of soils, than a local person. Do you think the farmer knows from within? I went to school, colleges and outside the country. If you are introducing a new technology you are the flag bearer (Interview September, 2012).

Evoking the above example in relation to river-based agricultural water use innovations, the agricultural officer observed that just like farmers are not aware of what to plant, they are equally ignorant about river-based agricultural water use innovations. The narrative was reverberated by the NAADS officer in the district. "Farmers actually [do] not need one to be purely democratic. Dictate over them and later they will appreciate. Farmers need to be exposed to make informed choices" (Interview, September 2012). The officers shared a concern that farmers are not in a position to detect appropriate farm inputs except with the intervention of agricultural experts.

In the field it was, however, revealed that farmers have not taken the above discourse lightly. They have staged resistance to new agricultural farm inputs enforced on them without taking into account their point-of-view. Farmers' resistance reflects the so-called "crude approach" where they decide what they want (Interview September, 2012).

Farmers choose what they want and can manage. For instance they do not hesitate to call you after the death of NAAD's cow. You [officer], *Ente yanyu ya NAADS efire* [literary meaning: you officer, your cow for NAADS [National Agricultural Advisory services] is dead. They [farmers] want quick money these days (Interview September, 2012).

In the quote above, although farmers receive the NAADS cow species, they literary do not acknowledge that it belongs to them. This is pronounced when the cow happens to die in the farmer's farm. Farmers demand that the NAADS officer go for [their] cow once dead. According to the district agricultural officer's voice, farmers want quick money these days and therefore resist anything as long as it does not promise what they want. Farmers have staged resistance against the so-called new farm inputs (cows), which are dictated upon them.

In respect to the above, was the farmer's standpoint on market distortions.

The tin for cabbage seedlings is cheap compared to the yield you harvest in case your cabbages yield well. But the market is so complicated. Sometimes your yield can be as much as three sacks full of cabbages. You struggle, take them to the market using the bicycle and the worst moment is the rainy season [because of the muddy road]. You buy sacks in which to put in the cabbages plus the pesticides. To your surprise the buyers come and want to pay you so little. When you compare the labor you used to grow them, the energy you have used to ride them to the market, you decide not to sell them. In the end you end

up not selling any. Normally I just abandon them at the market, pour them down and walk away with my sacks (Interview, September, 2012).

This was the case of a farmer who had improvised and put holes in a small plastic container. The container does not carry more than one liter of water or pesticide. Nevertheless, the farmer couldn't find market for his yield notwithstanding the tedious experience he underwent to have his crop yield and take it to the market.

The question of turnover remains crucial if a farmer is to venture into development or even adoption of agricultural innovations. It was noted that some farmers, who had made attempts to create equipment or initiate innovations to enhance agricultural produce, decried the unpredictable turnover albeit the cash expenses and drudgery, alongside their pressing basic needs. The same argument was advanced in the NAADS programme — quick money.

The experiences, so far, highlighted as in the case above, the need to reconcile agricultural innovations, in whatever aspect, with the agricultural turnover on the side of farmers, who are the active constituents in agriculture. The findings resonate with Tiffen and Mortimore's observations that farmers' capacity to innovate follows "necessity [and] farmers' real cost of their own or hired labor" (Tiffen and Mortimore 1994: 998). Calling to mind the objective of the paper, farmers in water endowed areas also require water use innovations — equipment to withdraw water and water management techniques to control water effects. Farmers need water use innovations to withdraw water to use in the regular activities of crop growing such as in pest control but also to enhance plant growth during the sunny season. Water storage is not yet a common phenomenon in water resourceful areas although it is necessary. Market distortions albeit the drudgery encountered in farming have become challenges to farmers in this area. Market distortions risk causing seasonal farming in this area. Farmers prefer farming in the sunny season rather than in the rainy season so that they can be sure of market for their produce, an option that became possible because of the river-based agricultural water use equipment and water management techniques. In this regard, farmers have coped with the unreliable rainfall patterns and reduced poor farm yields. Market distortions, however, emerge as another challenge, reducing farming activity in the rainy season and encouraging planting in the sunny season. Either way, the area is susceptible to unstable food supply.

In addition, findings revealed that spraying of pesticides was one of the regular activities in which river-based agriculture equipment was put to use by most farmers. The level of intoxication of the river was not ascertained in this research. There is need to explore the level of intoxication, pesticides that cause this and mechanisms to protect the river.

The findings also revealed that successive environment policies increasingly restrict river-based water use innovations in the area, without providing alternative water use techniques to farmers. This has widened the gap between surface water policy and farmers' activities. This partly accounts for the state of art of river-based agricultural water use innovations in the area — the lack of river-based agricultural water use initiatives in the district, not to mention the lack of an operational framework for water for production at the national level. The environment and agriculture departments in the district relegated river-based agricultural water use innovations to farmers. In addition, the departments hardly worked in collaboration. They all have the same clientele (farmers) and have one major area of activity (water). Environment policies are still a dilemma for river-based agricultural water use innovations. The policies restrict agricultural activity and withdrawal of water from rivers, though these regulations have not yet been scaled out.

The basic thesis for this paper has been that river-based agricultural water use innovations in water resourceful areas is equally significant in agricultural production. Nonetheless, they have been marginalized in the national and district activities and relegated to farmers. Farmers are left to subsist on their own. Environment policies continue to implicate agriculture activity. This has led to the exclusion of agriculture planning and implementation from river (natural water resources) planning and finally the rural farmer. River-based agricultural water use innovations in the district remain a preserve of the farmer, amidst successive government regulations on agricultural activity along rivers. There is need to envisage a working relationship between agriculture and the environment, given the necessity of river-based agricultural water use innovations in the district.

References

- Benin, S., Thurlow, J., Diao, X., Kebba, A. and Ofwono, N. 2012. Uganda. In *Strategies and priorities for African agriculture. Economywide perspectives from country studies*, edited by X. Diao, J. Thurlow, S. Benin and S. Fan. Washington: International Food Policy Research Institute, pp. 281-315.
- Biswas, A. K. 2008. Integrated water resources management: Is it working? *Water Resources Development*, 24 (1): 5-22.
- Dugard, J. 2010. Can human rights transcend the commercialization of water in South Africa? Soweto's legal fight for an equitable water policy. *Review of Radical Political Economics*, 42 (2): 175-194.
- Goldwin, A. J. 2010. Water policy in South Africa: Trust and knowledge as obstacles to reform. *Review of Radical Political Economics*, 42 (2): 195-212.
- Harvey, P. 2008. Poverty reduction strategies: Opportunities and threats for sustainable rural water services in Sub-Saharan Africa. *Progress in Development Studies*, 8 (1): 115-128.

- Inocencio, A., Sally, H. and Merrey, D. J. 2003. Innovative approaches to agricultural water use for improving food security in Sub-Saharan Africa, Working paper 55. Colombo, Sri-Lanka: International Water Management Institute.
- Innovation Systems and Clusters Program-Uganda. 2011. Climate change innovations and entrepreneurship research report. Kampala.
- International Fund for Agricultural Development (IFAD). 2011. *Rural poverty report: New realities, new challenges, new opportunities for tomorrow's generation*. Rome.
- Kabarole District Local Government. 2007. 2002 Population and housing census analytical report. Uganda: Kabarole District Council.
- Luzi, S., Abdelmoghny, M. H., Sigrist, F. and Tauchnitz, E. 2008. Water policy networks in Egypt and Ethiopia. *Journal of Environment Development*, 17 (3): 238-268.
- Ministry of Agriculture, Animal Industry and Fisheries (MAAIF). 2010. Agriculture for food and income security. Agriculture sector development strategy and investment plan 2010/11-2014/15. Kampala: MAAIF.
- Ministry of Finance, Planning and Economic Development (MFPED). 2008. Gender dynamics in agriculture in Uganda: What are the key policy considerations? Policy Summary Paper 3. Kampala: MFPED.
- Ministry of Finance, Planning and Economic Development (MFPED). 2008. Agricultural sector investments and institutional performance in Uganda. Discussion Paper 17. Kampala: MFPED.
- Ministry of Local Government (MoLG). 2007. Environmental checklist for sub county/division/town council local governments. Kampala: MoLG.
- Ministry of Tourism, Trade and Industry. 2006. Kabarole District tourism plan. Kampala: Ministry of Trade and Industry.
- Ministry of Water and Environment (MWE). 2010. Ministry of Water and Environment sector performance report. Kampala: Ministry of Water and Environment.
- Ministry of Water and Sanitation. 2006. Ministry of Water and Sanitation sector performance report. Kampala: Ministry of Water and Sanitation.
- National Agricultural Advisory Services (NAADS). 2010. NAADS in Kabarole 2002/03-2009/10. Counting 8years later. A publication of the office of the Kabarole District NAADS Co-ordinator. Uganda.
- Nhamo, G. and Inyang, E. 2011. Framework and tools for environmental management in Africa. Dakar: Council for the Development of Social Science Research in Africa.
- Obeng-Odoom, F. 2012. Beyond access to water. *Development in Practice*, 22 (8): 1135-115.

- Republic of Uganda (RoU). 1995. The National Environment Act. Entebbe: Uganda Printing and Publishing Corporation.
- Republic of Uganda (RoU). 1999. A National Water Policy. Kampala: Ministry of Water, Lands and Environment.
- Republic of Uganda (RoU). 2010. National Development Plan (NDP) (2010/11-2014/15). Kampala.
- Scherr, S. J. 2000. A downward spiral? Research evidence on the relationship between poverty and natural resources degradation. *Food Policy*, 25: 479-498.
- Tiffen, M. and Mortimore, M. 1994. Malthus controverted: The role of capital and technology in growth and environment recovery in Kenya. *Journal of World Development*, (22) 7: 997-1010.
- United Nations Conference on Trade and Development (UNCTAD). 2011. Water for food –Innovative water management technologies for food security and poverty alleviation. New York and Geneva: United Nations.

Approaches to Agricultural Water Utilization and Management for Poverty Alleviation: A Case of Makonde District, Mashonaland West Province, in Zimbabwe

Esther Sigauke and Rumbidza D. Katsaruware

Abstract: Zimbabwe has been experiencing scarcity of water due to climate change. This has prompted the agriculture-dependent population to device coping strategies, to mitigate impacts of climate change, whilst reducing poverty. In this paper, innovative water resource utilization and management approaches that play a critical role in poverty alleviation are examined. Data was collected through questionnaires, interviews and field observations. A sample size of 249 farmers was used for questionnaire distribution. Interviews were conducted with Agricultural Extension (AGRITEX) and the Zimbabwe National Water Authority (ZINWA). The findings reflect that various innovative approaches of water utilization and management are in place, in Makonde District, and have resulted in poverty alleviation among the farmers. In light of the research findings, it is apparent that innovative approaches to water utilization and management are critical in poverty alleviation among smallholder farmers. Thus, environmental policy-makers should formulate policies that encourage farmers to use these techniques.

Keywords: water utilization, management, innovative approaches, poverty alleviation

1. Introduction

Water is a vital resource with crucial importance for sustainable development, including poverty eradication and food security (UNESCO 2013). This makes it crucial to improve water security. Water security, in a broader context, implies that all people, including the poor, have access to water services and sanitation to meet their basic needs (Pariyar 2004). However, water security has been threatened due to climate change. In addition, human behaviour has an impact both on water and on the global ecosystem, hence there is need to regulate human behaviour, in order to stabilize and sustain our future (Corvalan et al. 2005).

Global water resources are limited, with 85 per cent of the world's human population living in the drier half of the Earth (UNESCO 2013). Thus, a more sustainable approach to water management, and more equitable and ecologically sensitive strategies of water allocation and use, are required if the international development targets for poverty reduction set for 2015 are to be met (DFID 2000). Critical to this problem, is the growing human

population and the increasing demand for water by agriculture and industry. The problem of limited water resources is exacerbated by the rapidly increasing demand for the resource as well as a dread of demand outstripping supply (Carr 1997).

Agriculture relies heavily on water and plays an important role in the socioeconomic wellbeing of many people, more so farmers. In Africa, sustainable economic development is based on development of the agricultural sector, which is a major source of livelihood for 70 per cent of the population (World Bank 2000). However, agriculture is adversely affected by climate change and variations. The newest projections of the impact of climate change suggest dramatic negative impacts on crop yields in much of the developing world as a result of temperature and rainfall changes (Scherr et al. 2012). This has driven significant water innovation practices of water utilization and management that address persistent agricultural challenges facing the world. There is need for innovations that will reduce hunger, and improve environmental and agricultural sustainability and livelihoods. Given that one-third of the population of Sub-Saharan Africa (SSA) is undernourished and hence poor, there is need to improve the livelihoods of rural and urban communities through the management of water resources (World Bank 2000). The increased income from agriculture means an increase in availability of daily human necessities, such as water, food, clothing, and shelter, and financial capability for education and other responsibilities.

In Zimbabwe, the globally-induced economic crisis, population growth and migration are causing an increase in agricultural activities, yet Zimbabwe has been experiencing scarcity of water due to climate change. This has compelled the agriculture-reliant population to device strategies to mitigate impacts of climate change whilst alleviating poverty. In addition, the rising costs of new sources of water to meet the increasing demand have called for innovative ways and cost-effective strategies in water use and management. Thus, given this background, it becomes fundamental to investigate the link between water resources use as well as management and poverty alleviation in Mashonaland West Province, in Zimbabwe. Since Mashonaland West Province is regarded as the bread basket of Zimbabwe, it becomes fundamental to evaluate innovative strategies that aim at improving the availability and more efficient use of the valuable water resource, in agriculture. Thus, the research aims at achieving the following objectives:

- (a) Identify innovative strategies implemented by communities, to ensure efficient utilization and management of water in agriculture, in Mashonaland West Province;
- (b) Evaluate the contribution of innovative water resources use and management, to agriculture and poverty reduction, in rural communities of Mashonaland West Province;

- (c) Assess the challenges and successes of the strategies that have been implemented in efficient water resources use and management by rural communities in Mashonaland West Province;
- (d) Identify measures that can be implemented to ensure efficient water use and management for poverty alleviation in Mashonaland West Province.

2. The Nexus between Water Utilization and Management, and Poverty Alleviation

Poverty can be defined as a condition characterized by severe deprivation of basic human needs, including food, safe drinking water, sanitation facilities, health, shelter, education, and information (Gordon 2005). Close to half of the world's 6 billion people live on less than US\$ 2 a day; conversely 1 per cent of the world's population has an income equal to that of the entire bottom 57 per cent (Singleton 2003). Innovative approaches to water utilization and management approaches in agriculture have the potential to reduce poverty levels, especially in rural areas. Poverty remains a predominantly rural problem, with 75 per cent of the world's poor living in rural areas (IFAD 2001). Thus, there is need to address poverty issues in the rural areas.

Agricultural development, based on water conservation and irrigation, is often considered a promising avenue for poverty alleviation in rural areas (Heilig et al. 2000). However, with increasing climate change and variability, there is need to come up with innovative approaches that will make agriculture productive, if poverty is to be reduced in rural areas. These approaches should be simple and cost-effective for farmers. For example, the availability of water for a domestic garden can contribute greatly to household food security and nutrition. Water harvesting techniques, development of wetlands for agriculture and drip irrigation systems can be adopted. According to DFID (2004), the relationship between agriculture and poverty reduction is explained by four main mechanisms:

- (a) The impact of improved agricultural performance on incomes of rural and urban dwellers;
- (b) The effect of reduced food prices, for both urban and rural poor;
- (c) Increased incomes for farmers, and the contribution of agriculture to growth and the generation of economic opportunities in the non-farm sector;
- (d) The fundamental role of agriculture in stimulating and sustaining economic transition, as countries (and poor people's livelihoods) shift away from being primarily agricultural towards a broader base of manufacturing and service industries.

Thus, when innovative approaches to water use and management are adopted in agricultural activities by rural communities, poverty can be alleviated. However, there is need to identify support systems that encourage innovation and enable adoption.

3. Research Methodology

3.1 Study Site and Description

Makonde District is located in Mashonaland West Province of Zimbabwe (Figure 1). The province is located in agro-ecological region II, where rainfall is above 900 millimetres per year. Farming is the major activity in the area. The major crops grown are tobacco, cotton, wheat, and maize. Soils in the region are mainly red clay soils, which are highly fertile. Cattle are also widely reared in the district for dairy products and beef, on a commercial basis. Mashonaland West Province has six districts, including Makonde.

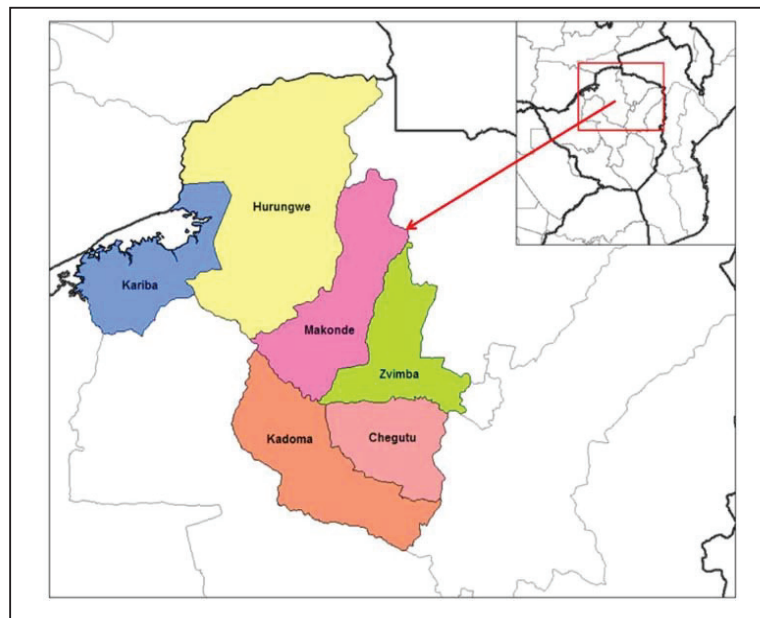


Figure 1: Study Area - Makonde District, Mashonaland West Province in Zimbabwe

(Compiled from survey data).

3.2 Research Design and Sampling Procedures

Descriptive case study research design was used. It involved a description and explanation of agricultural water management and utilization methods in Makonde District. Studying Makonde District as a case enabled studying

the characteristics of water management in the district in detail, thereby obtaining considerable and comprehensive information. The descriptive case study research design allowed patterns, processes and opinions on water utilization and management to be revealed.

Makonde District consists of 19 wards. Stratified sampling was used to divide the wards into upper, middle and lower strata. Stratification involved dividing the sampling frame (wards) into sub-groups. The Makonde District map was used to divide the district into upper, lower and middle strata (see Table 1).

Table 1. Summary of sampling procedure

Ward	Households	Strata	Percentage sample	Sample size
11	248	Upper	5	12
2	2,359	Upper	5	118
3	997	Middle	5	50
6	878	Middle	5	44
10	303	Lower	5	15
12	194	Lower	5	10

SOURCE: Survey data

Further, purposive sampling was used to select the wards for study. Purposive sampling involves selecting individuals as samples, according to the purpose of the researcher, and the individuals serve as controls. The major limitation of purposive sampling is that not all individuals (wards) were given an equal chance to be included in the sample. Out of the 19 wards, the urban and mining wards were eliminated because the study focus was on rural areas. Ward 19 was also eliminated because it was a new ward and there were no statistics on the population and household sizes of the ward. The eliminated wards were 7, 8, 9, 13, 15, 17 and 19. In the upper strata, wards 10 and 12 were selected using purposive sampling, based on the fact that there were some agricultural water utilization and management activities going on in the area. In the middle strata, wards 6 and 3 were selected based on the fact that some water utilization and management activities were evident. In the upper strata, wards 2 and 11 were selected, also based on the same criteria. Thus, the research was carried out in six wards.

Using a percentage of 5, a sample size was calculated for each ward as shown in Table 1. For each ward, there was random selection of the households during distribution of questionnaires. The questionnaire was used as the primary data collection instrument in the research because it helped to gather primary data from farmers within a short space of time. Thus, questionnaires were distributed to 249 farmers and the return rate

was 100 per cent. Interviews were also conducted and purposive sampling was used to select organizations to be interviewed. These organizations were selected because of their engagement with issues that relate to farming and water management. Interviews were conducted with AGRITEX and ZNWAEMA. The benefit in conducting interviews was that it yielded highly informative material, not obtained through questionnaires. This included policies, laws, and duties and responsibilities of authorities in water management.

3.3 Data Analysis

Data analysis was concerned with reducing masses of collected data into meaningful information. Data was organised and edited to remove outliers which would cause bias in the results. Data was analysed using Statistical Package for Social Science (SPSS) version 13.0.

4. Results and Discussion

4.1 Sources of Water in Makonde District

Table 2. Sources of water

Source of water	Number of respondents	Percentage
Well	35	7
Stream	4	1
Spring	4	1
River	75	15
Pond	5	1
Dam	170	34
Borehole	26	5
Roof top	5	1
Rainfall	174	35

N=249

SOURCE: Survey data.

In Makonde District, dam water is the common source of water, used mainly during the dry season for agricultural purposes. Dam water is used for irrigation. Agriculturally, the water stored behind the dam is released to provide water for crops during the dry season, or in times of drought and water scarcity. The water stored behind dams is discharged through pipelines or canals into other river systems, to make up for shortfalls in flow, in the receiving rivers. This makes water available to farmers downstream, even when the receiving river has little water, especially in the dry season. Dams thus, have an advantage of storing water until it is required downstream. The water discharged from the dams will then be

used for various purposes such as meeting domestic needs, crop and livestock production, as well as other small-scale industrial enterprises.

During the wet season rainfall is the predominant source of water used by smallholder farmers. Roof-top water harvesting is also practised by farmers during the rainy season. Water harvested from roof-tops is used to water homestead gardens. Smallholder farmers are the largest group in the agricultural sector, in most developing countries, producing more than 40 per cent of the world's food, and they rely on rainfed agriculture (Frausto 2000; Mupangwa et al. 2007). Thus, rainfall is an important source of water yet climate variability is one crucial factor which impacts on the ability to produce food among smallholder farmers, given that 60 per cent of farmers practise rainfed agriculture in SSA (Rockstrom et al. 2002).

Wells, streams and boreholes are another important source of water. Carrying water from these sources to the gardens, fields and homesteads requires a lot of labour. Some of the wells in Makonde are too shallow for use in the dry season. Using water from the streams requires treadles and motor pumps yet the high cost of these pumps puts them beyond the reach of Zimbabwe's smallholder farmers, which makes it more difficult to use streams as a water source.

4.2 Agricultural Water Utilization and Management Strategies

Table 3. Agricultural water utilization and management strategies

Strategy	Number of respondents	Percentage
Potholing	130	26
Semi-circular furrows	23	5
Mulching and manuring	190	39
Drip irrigation	50	10
Storm drains and canals	34	7
Tank storage	20	4
Intercropping	42	9

N=249

SOURCE: Survey data.

Mulching is widely practised by smallholder farmers in Makonde District during the dry season, for efficient water utilization through improving water penetration and reducing surface runoff. Mulching is a process of covering the soil to make favourable conditions for plant growth. Farmers in Makonde stated that with un-mulched beds they usually have to water the field thrice a week while with mulched beds, watering is only needed at least once a week. In addition, the number of days spent by a farmer without watering the field depends on the thickness of the mulch layer, material used in mulching and the type of soil in the area. However,

farmers in Makonde District did not have information on the quantities and methods of mulch application. This hindered effective conservation of moisture. Besides conserving soil moisture, mulching conserves time, energy and nutrients, and prevents soil erosion.

Smallholder farmers in Makonde District also practise potholing, whereby a crop is planted in holes or basins, largely for the purpose of harvesting water. This system is also known as basin tillage. The planting basins are prepared from June to October, after harvest of the previous season's crops. Planting basins are dug during the dry season and serve as permanent planting basins, which are maintained in all seasons. Fertilizer or manure is placed in the basin when the first rains manifest, then the crop is planted. The basins measure 15 centimetres in length, depth and width. Early preparation of basins facilitates early planting, which increases yield potential. Potholing is an agricultural conservation technique that aims at ensuring water enters the soil so that plants have sufficient water to attain potential growth. It also ensures that there is greater potential for increased cropping efficiency as more water is held in the soil profile, compared to the conventional system (Steiner 2002). Thus, conservation farming, through potholing, is one of the effective measures by which soil water content can be increased effectively in arid and semi-arid areas (Willis and Bond 1971; Arshad et al. 1995).

Although there are benefits associated with basin tillage, a number of challenges inhibit its successful implementation in Makonde District. The technique is labour intensive and the requirement of increased labour to dig and maintain the basins, makes the technique unfavourable. Moreover, continuous weeding is required due to rampant weed infestation. Where there is retention of crop residues, this has resulted in termite infestation. This makes the technique time consuming since a lot of time is spent maintaining the holes and weeding.

The drip irrigation system is used by farmers as a strategy of water utilization in Makonde District. Drip irrigation involves a network of pipes and valves that avail water directly to the plant root zone, through dripping. The farmer creates shallow trenches so that water is stored in the furrows, which has the advantage of saving water. Drip irrigation technology applies water slowly and directly to the root zone of the targeted plant. Farmers indicated that they avoid leakages in irrigation in order to efficiently utilize the available water. They do so by maintaining irrigation systems. When the pipes or valves are damaged, the farmers try to repair the damages. However, the farmers cited that in most cases it is difficult to repair these damages since the irrigation equipment is owned communally. In the year 2000, the white farmers left their farms, through the 2000 land reform programme. Farms were subdivided into smallholder production units, known as A1 schemes, hence a farm that was previously owned by one farmer could now be owned by ten farmers. This meant that farmers who

settled on one farm could share farming equipment such as irrigation systems, which made maintenance of the irrigation systems more difficult.

Intercropping is another strategy practised by farmers in Makonde District. It involves planting two or more crop at the same time such as maize and beans. In this case, moisture is preserved as the under crop (beans) prevents direct sunlight thus preserving moisture. This technique is a common traditional crop production practice used on small farms with limited production capacity due to lack of inputs. Intercropping has been practised as a result of declining land sizes and the need to enhance food security among the farmers. The yield advantage associated with the intercropping system is as a result of light, water and nutrients that are effectively converted to biomass by the intercrop, in time and space, due to differences in the competitive ability of these crops (Ramradi 2010). Intercropping, therefore, results in higher yields, improved security and poverty reduction through sale of surplus produce (Mucneke 2007).

Storm drains (Figure 1) are used by smallholder farmers in Makonde District, to channel rainwater towards the dams. These are specialized drainage systems designed to handle an excess of water as a result of flooding or heavy rainfall. Although storm drains are an effective method of water utilization, they require sound management. In Makonde, farmers failed to maintain the storm drains, hence weeds began to grow in the drains. This causes blockages that prevent effective channeling of rainwater. In addition, cattle stamping causes sand to infiltrate the storm drains, causing blockages.

Canals are also used in Makonde District to move the water from the source to the fields. The movement is enabled by the force of gravity that naturally moves water from the uplands to the lowlands. These are very important during the dry season as they are directly channeled into the farmer's fields, where they supply water for irrigation to horticultural crops such as vegetables. When the canals reach the fields they are diverted into various smaller semi-circular furrows (Figure 2), to supply water into each furrow. It is along these furrows that vegetables are planted. The depressions associated with these furrows ensure that all the water available is swiftly channeled towards the crops only, hence no significant amount of water is lost through run-off or overflow.

**Figure 2: A: Storm Drain with Weeds**

Source: Adapted from survey data

**Figure 3: Semi-Circular Furrows**

Tank storage is another strategy practised by farmers in Makonde District. The bigger the tank, the greater the amount of water stored. Farmers can afford to buy small, cheaper tanks with a 200-litre capacity. The tanks are mainly used for homestead gardens and livestock production.

4.3 Contribution of Water Use and Management in Poverty Alleviation

Table 4. The contribution of water resources use and management in poverty alleviation

Poverty reduction	Number of respondents	Percentage
Household food security	236	62
Employment creation	23	6
Supplementary income	60	16
Education	19	5
Health	42	11

N=249

SOURCE: Survey data.

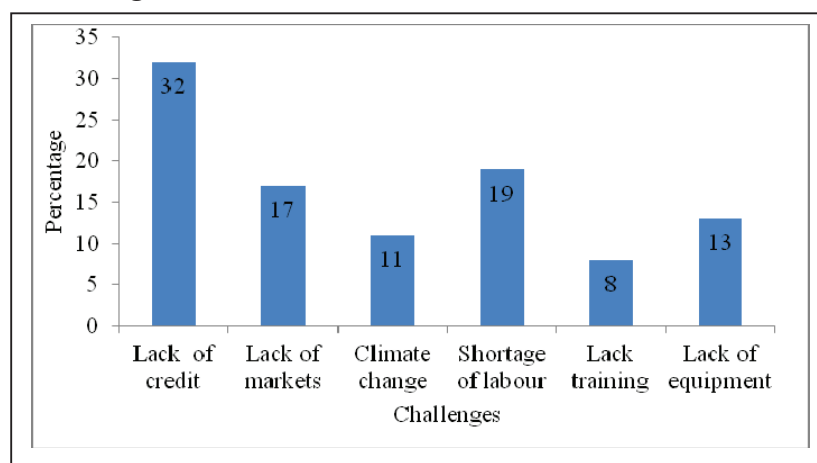
The strategies that have been implemented by farmers to ensure efficient utilization of water resources have proved to be beneficial in achieving poverty alleviation. In Makonde District, water utilization strategies have enabled farmers to obtain sufficient food for household needs, thus reducing malnutrition levels. Innovative agricultural technologies are the key to poverty reduction (UNCTAD 2011). Thus, to achieve food security, resources such as water and land need to be used more innovatively. This is mainly necessitated by changing climatic conditions, characterized by droughts, mid-season droughts, unpredictable rainfall, and high temperatures that are beginning to have a significant effect on crop yields as well as declining water tables.

Through innovative utilization of water resources, smallholder farmers have managed to educate their children. Farmers are able to produce more food for sale and can send their children to school. Education is thus a vital tool because its role in poverty reduction cannot be underestimated, as no country has successfully eradicated poverty without educating its people (Mtey and Sulle 2013). Education gives people skills that allow them to produce more for the country, thereby reducing poverty.

Community members have been employed as farmworkers engaged in crop or livestock production. This reflects poverty alleviation. Employment and the quality of employment is crucial for poverty reduction (Ernst and Berg 2009). Hence, employment is an essential tool in the fight against poverty.

Supplementary income is the money obtained from the sale of surplus produce. Farmers in Makonde indicated that water utilization strategies have enabled them to get extra income from the sale of surplus produce. A comparison of the supplementary income obtained by farmers who practised conservation agriculture and those who did not practise agriculture revealed that there were significant differences ($\alpha/\alpha=0.05$; $p/\text{probability} < 0.002$) in supplementary income between the two groups. Farmers practising conservation agriculture had more income (mean 217.40) than those not practicing conservation agriculture (mean 111.35).

4.4 Challenges in Adoption of Innovative Water Use and Management Strategies



N=249

Figure 4: Challenges in Adoption of Innovative Water use and Management Strategies

Source: Compiled from survey data

Farmers are faced with various problems that hinder them from successfully adopting innovative agricultural water use and management strategies. Lack of credit is a major limitation yet it is a vehicle which enables farmers to participate fully in water utilization projects, thereby improving their wellbeing. In addition, credit can help alleviate poverty when loans are used to finance sound investments and innovative projects with cash-flow prospects, allowing for profit and margins for loan repayment.

Shortage of labour is a factor influencing effective participation of farmers in water utilization and management. The use of basins in potholing requires high labour to dig the holes and maintain them. Yet in most cases, family labour is what is used on the farms. It is expensive for farmers to hire labour.

Smallholder farmers lack access to markets to sell their produce. Farmers who specialize in market gardening need ready markets since they focus on perishable products. The farmers cited that that one reason they cannot improve their living standards is that they face difficulties in accessing the market. This is mainly linked to being situated in remote areas along with high transport costs. The inability of farmers to access markets means that they lack income for inputs, consumer goods and asset accumulation, hence they remain poor. Farmers also lack the equipment to perform farming activities efficiently. Equipment such as irrigation pipes and valves are required by farmers, yet are expensive to purchase. Thus, farmers remain vulnerable to poverty. Lack of training is yet another challenge for farmers, which is a handicap that prevents effective operations in the farms. Although AGRITEX has a role of providing training, information and extension services to farmers, the department is handicapped by financial constraints. For example, the extension officers require motorbikes to travel from one farm to another, which the government does not provide.

Climate change is also a drawback to farmers in Makonde District, and presents threats to development at the same time. It is the vulnerable and marginalised who have the least capacity or opportunity to prepare for the impacts of changing climate, or to participate in negotiations on mitigation (Brody et al. 2008). Thus, due to climate uncertainties, it is difficult for poor farmers to plan effectively for farming activities, hence they remain poor and constantly vulnerable to the effects of climate change.

5. Conclusion and Recommendations

It is apparent that innovative agricultural water utilization and management approaches can significantly alleviate poverty among smallholder farmers. Mulching, potholing, storm drains, intercropping and drip irrigation are vital methods of water use and management that need to be encouraged among farmers, if poverty is to be reduced. Through adopting innovative agricultural water utilization and management approaches, poverty can be alleviated through household food security, employment creation,

education, health, and supplementary income. In order to promote innovative agricultural water utilization and management a permitting environment is required. Yet farmers are faced with challenges that limit their capacity to adopt innovative strategies for water utilization and management. Therefore, for the approaches adopted by farmers to be viable, there is need to address the challenges faced by farmers.

In light of the research findings, this paper recommends that AGRITEX needs to train farmers on innovative approaches in agriculture water use and management, not only during the wet season but during the dry season as well. There is need for government to intervene and provide financial support that would allow extension officers to train farmers. Besides training, institutions that offer credit should partner with smallholder farmers and policy-makers should formulate policies that encourage farmers to adopt these approaches.

References

- Arshad, M. A., Gill, K. S. and Coy, G.R. (1995). Barley, canola, and weed growth with decreasing tillage in a cold, semi arid climate. *Agronomy Journal* 87: 49–55.
- Brody, A., Demetriades, J. and Esplen, E. 2008. Gender and climate change: Mapping the linkages. A scoping study on knowledge and gaps. BRIDGE, Institute of Development Studies (IDS). University of Sussex, UK.
- Carr, M. 1997. *New patterns: process and change in human geography*. UK: Nelson Thornes.
- Corvalan, C., Hales, S. and McMichael, A. 2005. Ecosystems and human wellbeing: Health synthesis. A Report of the Millennium Ecosystem Assessment. Geneva: WHO Press.
- Department for International Development (DFID). 2004. *Agriculture, growth and poverty reduction*. London: DFID.
- Department for International Development (DFID). 2000. Target strategy paper: *Water resource sanitation*. London: DFID.
- Ernst, C. and Berg, J. 2009. The role of employment and labour markets in the fight against poverty. *Promoting pro-poor growth: Employment*. Geneva: OECD.
- Frausto, K. 2000. Developing options for small farmers: Harnessing the potential of the poor. Contributing papers to the World Commission on Dams. Prepared for Thematic
- Review IV.2: Assessment of Irrigation Options. Institute Development Enterprises. London: Earthscan.

- Gordon, D. 2005. Indicators of poverty and hunger. Presentation to Expert Group Meeting on Youth Development Indicators, December 12-14. NY: United Nations Headquarters.
- Heilig, G. K., Fischer, G. and Velthuisen, H. 2000. Can China feed itself? An analysis of China's food prospects with special reference to water resources. *International Journal of Sustainable Development and World Ecology*, 7: 153-172.
- International Fund for Agricultural Development (IFAD) 2001. *Rural poverty report 2001: The challenge of ending rural poverty*. Oxford: IFAD.
- Mtey, K. P. and Sulle, A. M. 2013. The role of education in poverty reduction in Tanzania. *Global Advanced Research Journal of Educational Research and Review*, 2 (1).
- Mucneke, C. O., Ogwuche, M. A. O. and Kalu, B. A. 2007. Effect of planting density on the performance of maize-soyabean intercropping in a guinea savanna agroecosystem. *African Journal of Agricultural Research*, 2: 667-677.
- Mupangwa, W. and Tomlow, S. 2007. Effect of minimum tillage and mulching on maize yield and water content of clay and sandy soils. *Physics and Chemistry of the Earth*, 32: 1127-1134.
- Pariyar, M. P. 2004. Water and poverty linkages in mountainous areas: Case study from Nepal. In *Water and Poverty Linkages: Case Studies from Nepal, Pakistan and Sri Lanka*. Colombo, Sri Lanka: International Water Management Institute (Project Report), Integrated Water Management Institute.
- Ramradi, M. 2010. Effect of maize-cowpea intercropping on light distribution, soil temperature and soil moisture in the environment. *Journal of Food, Agriculture and Environment*, 8: 102-108.
- Rockstrom, J. and Borron, J. 2002. Rainwater management for increased productivity among smallholder farmers in drought prone Environments. *Physics and Chemistry of the Earth*, 27: 949-943.
- Scherr, S., Shames, S. and Friedman, R. 2012. Climate-smart agriculture to climate-smart landscapes. *Agriculture and Food Journal*, 1:12.
- Singleton, D. 2003. Poverty alleviation: The role of the engineer. *Arup Journal* 1/2003. Brunel International Lecture 2002/03.
- Steiner, K. 2002. Conservation tillage, a gateway to food security and sustainable rural development: Producing in harmony with nature through conservation tillage. Harare, Institute of environmental Studies.
- United National Educational Scientific and Cultural Organizations (UNESCO) 2013. Strengthening fresh water security for peace and sustainable development. Consultation meeting with member states.

- United Nations Conference on Trade and Development (UNCTAD) 2011. Water for food — innovative management technologies for food security and poverty alleviation.
- UNCTAD current studies on science and technology innovation No. 4, United Nations, New York.
- World Bank. 2000. *World development report 2000/2001: Attacking poverty*. NY: Oxford University Press.
- Willis, W. O. and Bond, J. J. 1971. Soil water evaporation: Reduction by simulated tillage. Soil Science Society of America Proceedings.

Harnessing Water for Poverty Alleviation: Water Resource Use and Management in Informal Irrigation Schemes in Nyamaropa Communal Lands, Zimbabwe

Krasposy Kujinga

and

Sunungurai Dominica Chingarande

Abstract: Informal irrigation has a long history, which dates back to pre-colonial Zimbabwe. The practice is not officially recognized though it supports and sustains a significant number of rural households. This study was undertaken in Nyanga District, in Nyamaropa communal lands. Quantitative and qualitative data collection methods were used. Underpinned by the actor-oriented approach, the study observed that informal irrigation plays a critical role in ensuring household food security, and has the potential to generate income. Both men and women take an active role in this economic activity. A variety of crops are grown by informal irrigators during different times of the year. Challenges encountered by the irrigators include use of inefficient traditional irrigation methods, access to market and access to adequate inputs. There is need for a change in policy so that the practice can attract the necessary attention and assistance. This will ensure the adoption and promotion of efficient forms of technologies as well as better markets for farmers.

Key words: Informal irrigation, water, management, crop production, Nyanga, Zimbabwe

1. Introduction

Informal irrigation has been practised in different parts of Africa since pre-colonial times (Adams and Andersen 1988; Adams 1992). This activity uses a substantial amount of water yet it has not been the focus of research and policy-making, not only in Zimbabwe, but in other Southern African countries, such as Tanzania, due to its informality. Focus has predominantly been on formal irrigation schemes initiated and managed by governments (Bolding et al. 1996). Consequently, this has affected the organisation of the activity and the extent to which farmers could maximally derive benefits from it. The main reason behind disregarding informal irrigation is because engineers have tended to adopt a strict definition of irrigation farming that excludes much of Africa's informal irrigation systems (Adams 1992). Limited empirical research on the practice, owing to its informality, meant that the dynamics surrounding informal irrigation have not been brought to the attention of policy-makers for them to recognise its importance in poverty alleviation in contexts of

high poverty levels. From this viewpoint, this paper traces the history of informal irrigation in Nyamaropa communal lands in Nyanga District, analyses the water resources management systems in place, the gender dynamics in this practice, the contribution of the practice to the livelihoods of households involved in the activity, and the challenges encountered in the practice of informal irrigation and how informal irrigators cope with them. The paper draws on findings and discussions from a one-year project that used both qualitative and quantitative approaches, with financial support from the Organisation for Social Science Research in Eastern and Southern Africa (OSSREA).

The paper shows that despite lack of official recognition, informal irrigation plays an important role in the livelihoods of the irrigators and their households. Its resilience over the years testifies to its importance, to both men and women. However, conflict over water resources, lack of markets, and erratic supply of inputs have affected the extent to which farmers have benefitted from the practice, in view of the absence of any form of assistance from both the state and non-state actors. It is important that this practice be recognized and appropriate policies are put in place to improve the situation of informal irrigators, with regards to water use and management as well as livelihoods sustainability.

1.1.1. Background

Informal irrigation is not unique to Zimbabwe, but is practised in a number of countries using different names such as indigenous or traditional irrigation farming (FAO 2005). Traditional irrigation farming has the advantage of being embedded in local people's culture (embracing religious beliefs and value systems as well as art, technology and science). It is technical, in the sense that it is based on experience; it is personal, particular, intuitive, implicit, integral, and communal (shared). Under these systems, ideologies and indigenous technologies are critical (Adams, 1992; Adams and Andersen, 1988). In contrast, modern ways of irrigation are external and impersonal (Adams and Andersen, 1988).

In Zimbabwe, the activity is mainly referred to as informal irrigation farming, owing to lack of official and legal recognition of the activity. The informal irrigation sector in Zimbabwe has an estimated area of about 20,000 hectares and is clearly the largest stakeholder category, in terms of area, amount of water used and number of families depending on it. Despite this, the water resources management principles in these schemes have not been well appreciated by state institutions responsible for water management. The law, in fact, criminalises informal irrigation farming as many of those involved in it utilise water without formal water permits. As a result, informal irrigators do not get much support from the state for enhancing crop production as well as improving water management systems. Government support is channelled towards the formal smallholder irrigation schemes as a measure to improve agricultural productivity and incomes in the rural areas.

Dearth of empirical research and policy recognition of informal irrigation has led to the assumption that irrigation systems initiated and run by informal irrigators are non-existent in Zimbabwe. As a result, the vital role played by this economic activity in sustaining livelihoods of the farmers through food production for household food security and income generation has remained hidden. Gender dynamics in informal irrigation and in the discourse of water rights, informed by women's cultural relationship to water, has also remained unexplored. Furthermore, the innovations and agency by local communities in informal irrigation as well as water management practices have not been explored.

1.1.2. Theoretical Framework

This study utilizes the Actor-oriented framework to analyse water resources management and use for informal irrigation and its role in enhancing livelihoods (Long 1992; Long and van der Ploeg 1994).

The actor-oriented framework places more emphasis on local actors as influencing and shaping the development process and outcomes in their areas (Long 1988; Long 1992; Long and van der Ploeg 1994). The social actor is the entry point in an actor-oriented analysis. The term "social actor" is a social and cultural construction, where individuals and institutions are metaphorically transformed into social actors (Magadlela 2000: 14). In this study, social actors refer to individual households and communities practising informal irrigation. Other actors in the study include government departments such as the ministries of water, agriculture and rural development as well as non-governmental organisations (NGOs) working with communities.

The actor-oriented framework is a suitable tool for analysis since it facilitates the identification of the different actors, their interests, objectives, and organizing strategies as they interact with other actors (Magadlela 2000).

The concepts of the actor-oriented framework that are used in this study include lifeworlds, agency, heterogeneity, social interface, and networks. The concept of lifeworld is used to analyse how informal irrigators have played a role in shaping and reshaping their activity (that is, the innovations over time) as well as how they view themselves, their situation, and their everyday lives, and encompasses how they view the outside world and interpret their situation, and their interpretations of new innovations using their conceptual tools acquired in their world view (Long and Villwereal 1994).

The concept of human agency "attributes to the individual and community informal irrigators the capacity to process social experience and to devise ways of coping with life, even under the most extreme forms coercion" (Long 1992: 22). This clearly brings out the notion of innovation that has seen the resilience of the informal irrigation sector. Social actors or institutions should be seen as having the ability to process and formulate

strategies to cope with life's difficulties, such as those caused by drought and poor soils, which could have influenced a number of local communities to embark on informal irrigation farming. This introduces the concept of human agency, the idea that actors were knowledgeable and capable of devising ways of coping with life, even under the most extreme circumstances (Long 1992). Though a number of countries in Southern Africa have enacted different pieces of legislation that discourage the practice of community-based management of water for informal irrigation, the actors involved in this economic activity have not, to a larger extent, stopped practising this economic activity which, according to them, is viable. In a number of instances, as shall be seen later, informal irrigators as capable actors and agencies of change, have actually developed their own rules and regulations that govern the use of water resources in their irrigation operations (Adams 1992; Kujinga 2003).

The concept of social interface, defined as a critical point of intersection, or linkage, between different systems, fields or levels of social order, where structural discontinuities based upon differences of normative value and social interest were most likely to be found (Long and van der Ploeg 1989; Arce and Long 1992), is used to analyse the encounters of informal irrigators, relevant government ministries and departments as well as other stakeholders in informal irrigation.

The study also analyses the sociopolitical networks that informal irrigators were part of in order to adapt to the economic activity. The concept of heterogeneity is used to show that informal irrigators were essentially heterogeneous, by gender and even age (Long and Villwereal 1994), organising their activities differently and reacting differently to any outside interventions.

2. Methodology

2.1 The Study Area

The study was conducted in Nyamaropa communal lands, which fall under Nyanga District, Manicaland Province in Zimbabwe (Figure 1). Nyanga District is located in the Eastern Highlands of Zimbabwe, and stretches for some 140 kilometres along the eastern border of Zimbabwe with Mozambique (Kujinga 2010). The district has a width of about 40 kilometres. It is one of the seven districts of Manicaland Province. The northern part of the district is bound by the Nyangombe and Ruwenya rivers to the west and to the east by the Kairezi River, which forms the international border with Mozambique. Much of the district is dominated by the Nyangani Mountains, which form a chain of high ground running north-south, through the centre of the area (Cunliffe 1998; Kujinga 2010). Nyanga District contains portions of all the five agro-ecological regions of Zimbabwe (Surveyor General 1984). Agro-ecological or natural region I is confined to the higher, moisture-rich terrain of the Eastern Highlands. It covers virtually all the southern portions of the district and extends north,

along Nyangani Mountains. To the west, and curving round to the north, the lower portion of the district is mapped as strips of agro-ecological regions II, III and IV, with a small portion of agro-ecological region V occurring along the Matisi drainage basin, in the vicinity of its junction with the Kairezi River (Cunliffe 1998). Figure 1 shows the location of Nyanga District and the study sites within the district.

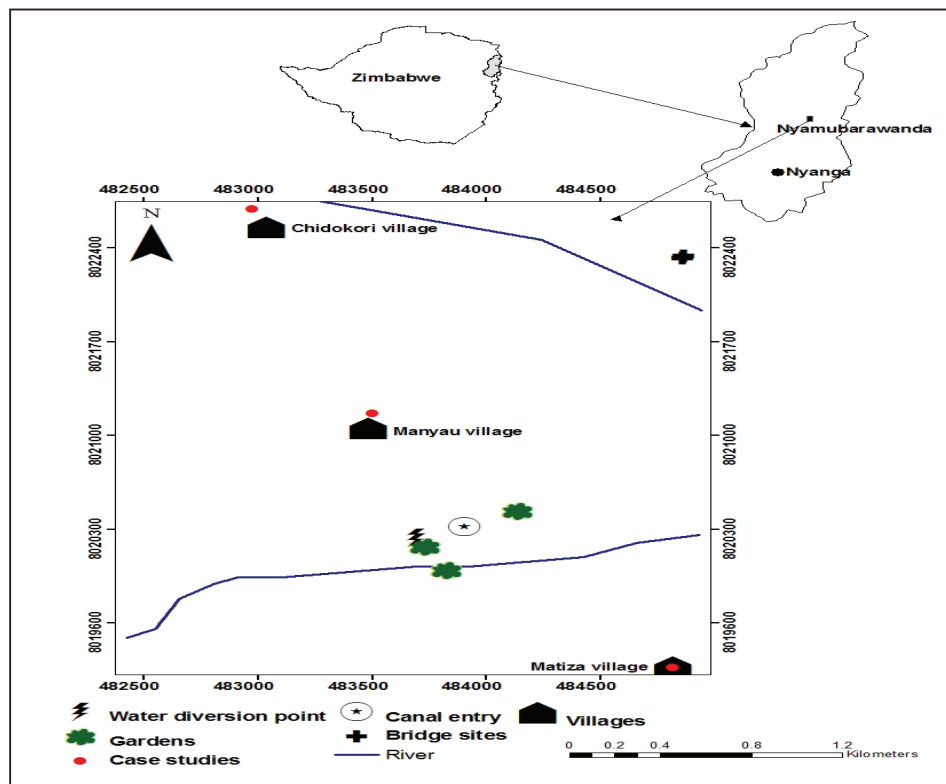


Figure 1: Study Area

(Department of Geography, University of Zimbabwe GIS laboratory).

According to the 2012 census, Nyanga District had a population of 125,688 (CSO 2012). Nyanga Rural District has 29 wards. Ward 13 (Nyamuburawanda ward) was purposively selected for this study. The community members in this ward practice informal irrigation all-year round and the practice has been going on for a number of decades. Ward 13 has the following villages — Chidokori, Chisoma, Dhlanjara, Manyau, Matiza, and Samanyika. According to the 2002 census, the ward had a total population of 2,551, which constitutes 2 per cent of the total district population (CSO 2012).

Nyamubarawanda ward is the catchment area of Morozi River and its tributary, Nyaurungo. Morozi River is also a tributary of the Kairezi River, which forms the boundary between Zimbabwe and Mozambique. Informal irrigation farming in the ward is practiced mainly along Morozi and Nyaurungo rivers as both are perennial. Five communally managed cluster gardens of different sizes are found in the Morozi catchment area. For purposes of this study, only the cluster gardens of Manyau and Matiza villages, along Nyaurungo River, and Chidokori along Morozi River, were selected. These were selected on the basis of the differences in organization that existed between them. Villagers in Manyau have an organized irrigation management committee, which runs the affairs of their cluster gardens. Matiza and Chidokori villagers do not have committees for managing their cluster gardens.

The villages are located in agro-ecological region II b⁺, which has an annual rainfall ranging from 750 millimetres to 1,000 millimetres (Agriculture and Extension Services <AGRITEX> 1993). However, the region sometimes experiences severe dry spells during the rainy season or the occurrence of relatively short rainy seasons, which impacts unfavourably on crops. (Ibid). This makes irrigation a more reliable method of farming than rainfed cultivation, in this area. Parts of Morozi and Nyaurungo rivers were located in natural region I, which receives high rainfall of more than 1,000 millimetres per annum (Magadlela and Hebnick 1995).

2.1. Data Collection Methods

The study employed qualitative and quantitative data collection methods. Qualitative data collection methods included key informant interviews with key members of the community, who included traditional leaders and some of the men and women who participated in the construction of water canals, as well as the children of the men and women who constructed the first canals during the first part of the 20th Century. Focus group discussions were conducted with ordinary community members in order to get information on their experience, opinions and perceptions about their involvement in informal irrigation. The focus group discussions were attended by both men and women irrigators, from the age of 18 years, upwards. Each focus group discussion was attended by a maximum of 20 people. Transect walks, which involved walking through informal irrigation fields observing the irrigation systems, crops grown and people working in the fields, were also undertaken with informal irrigators.

The quantitative approach focused on collection of quantifiable data using a structured household questionnaire. Information collected include general household characteristics, history of informal irrigation, crops grown, management of water for informal irrigation, nature and types of innovation being introduced by the irrigators, role of women in informal irrigation farming, contribution of informal irrigation to livelihoods, and

challenges experienced by informal irrigators and their views on the future of informal irrigation.

The quantitative survey used the household as the unit of analysis. A total of 100 questionnaires were administered in three villages. Household members involved in informal irrigation activities who are 15 years and above were interviewed. A 40 per cent sample size in all the settlements was adopted, using lists obtained from the national census, district council and local village leadership (see Table 1). Simple random sampling was adopted in the selection of the households, for purposes of questionnaire administration. Seventy per cent of the respondents for the study were females.

Table 1. Household questionnaires administered

Village	Number of questionnaires administered	Percentage of total (%)
Chidokori	39	39
Manyau	30	30
Matiza	31	31
Total	100	100

SOURCE: Study survey results

3. Results and Discussion

3.1 Background

The findings of this study show that the main livelihood strategy for households from Nyamubarawanda area is informal irrigation farming. The two most critical resources which the households/actors mainly depend on for sustaining their livelihoods are irrigable land and water. These findings tallied with findings of other studies, namely natural capital is the most accessible asset upon which rural households depend for their livelihoods (Motsholapheko et al. 2012; Kujinga et al. 2012, van der Linde et al. 2001; De Groot et al. 2003).

In terms of human capital (i.e education), there is no significance difference ($p = 0.730$) in terms of education for household heads across the three villages studied. The actors involved in informal irrigation generally possess high literacy levels. Forty-nine per cent (49 per cent) of the respondents went to school up to primary school level, 44 per cent completed secondary school and 1 per cent completed certificate level education. This shows that a sizeable percentage of informal irrigators have basic education, which they could use in the management of water resources as well as in individual farming activities. Six per cent (6 per cent) of the respondents indicated that they had never been to school. Significant differences ($p = 0.017$) were noted between male and female

Nyaurungo River to grow crops during winter when there was minimal water. This enabled them to realize better harvests.

The resettlement programme in the study area disturbed activities and lifeworlds of local actors (Bolding 2004; Magadlela 2000). In 1951/52, the then colonial government of Rhodesia strategically interfered with informal irrigation farming of the Barwe ethnic group by resettling displaced villagers of the Manyika ethnic group (from the Mutasa area in Manicaland Province) in Nyamaropa communal area. The Manyika ethnic group households were relocated in order to pave way for the establishment of a eucalyptus plantation in the Mutasa area. About 60 households, which later formed the Manyau and Matiza villages, were resettled on either side of Nyaurungo River. The Barwe ethnic group was instructed to make way for the new settlers and had to go and settle along Morozi River, where they formed Chidokori village.

Settling in an area that already had its established lifeworld, caused the Manyika ethnic group to gradually adopt the lifeworld of the Barwe ethnic group. The new settlers first experienced a lifeworld of dryland farming and realised that the area becomes water logged during summer, impacting negatively on the growth of crops. This fairly similar situation created a heterogeneous reaction from the different Manyika households as some of the new households decided to relocate to other communal areas where they thought they would be able to harvest more crops, while others decided to stay. In 1957, as a result of low yields sustained by rainfed agriculture and emigration from the villages of Matiza and Manyau, agricultural extension workers allocated the new settlers informal irrigation gardens for growing mainly vegetables and other crops during winter. The new arrivals were to use the canals that had been constructed by members of the Barwe ethnic group.

By 2012, the villages of Manyau and Matiza had over 80 households each. Population had increased, mainly due to natural growth. The villages had also experienced the immigration of new settlers who came anticipating to acquire informal irrigation gardens. This increased demand for gardens. In 2012, about 60 households in these two villages had informal irrigation gardens. There is also a high exchange of garden ownership through leasing and inheriting from relatives. "One garden per household" is the norm.

3.3 Water Resources Management Systems Under Informal Irrigation

Informal irrigation practices across the world widely use traditional flood irrigation methods and irrigation actors in Nyamubarawanda area are no exception (Bolding et al. 1996; Watson et al. 1998; Yabes 1992; Underhill 1990). There is no significant difference ($p = 0.230$) in irrigation methods used across the three villages studied as the use of earthen canals to convey water to the fields is still very common. The crops are irrigated using the flooding irrigation system, which is used by 93.7 per cent of irrigators in all the three study sites. For informal irrigators to go beyond the use of earthen

canals and flood irrigation, they will have to invest some financial and material resources, which most of them stated they do not have. Methods of irrigation have now progressed to include those that are water efficient and effective such as the use of sprinklers, drip irrigation and hydroponics (Zacchini et al. 2009). Informal irrigators cannot receive government assistance for investing in more advanced forms of irrigation, mainly because their activity is not officially recognized. The use of earthen canals and flood irrigation makes it difficult for the irrigators to determine the amount of water lost through seepage and actual crop water requirements for the different crops grown. It is, therefore, important to note that there are limits to human agency as a result of lack of institutional recognition, financial and material resources.

In some areas where informal irrigation is practiced, the actors have been able to put in place structures for management of the systems (Perreault 1998; Watson et al. 1998; Adams 1992; Underhill 1990). The concept of a management structure in Nyamubarawanda only exists among Manyau village informal irrigators. The management structure, as an actor, was put in place in 1992. The committee is tasked with management of the main canals, water distribution and general maintenance of the cluster garden area. For example, during the dry months of July to September, when demand for water is high, the committee managed to resolve conflicts related to water distribution by introducing a system of turns, whereby one gets water for a maximum of three hours. Only four plot holders can irrigate at any one particular time. Furthermore, farmers are advised to grow fewer crops. Another achievement of the management committee is the sourcing of fencing material erected around the 6.5 hectare garden, from the then Natural Resource Board in 1992. This was done so as to protect their produce from domestic and wild animals as well as conserving trees, which were usually cut down to fence individual gardens.

Conflicts over water are common every year, between July and September, which are dry months. Water diversions result in increased conflicts amongst users. The situation is made worse by the fact that there is no interface which takes place between irrigators from different villages to discuss issues related to water allocation. When water from the river becomes low, especially during the dry season, downstream users are usually disadvantaged by the upstream users who get most of the water.

3.4 Gender Dynamics under Informal Irrigation Farming

There is no significant difference ($p = 0.154$) between the participation of men and women in informal irrigation in the study area. Ninety-five (95) per cent of women and 93 per cent of men participate in informal irrigation. Tangible benefits realised from informal irrigation make the activity appealing to participants who are 15 years and above. Gendered division of labour is however evident in informal irrigation. One participant at one of the focus group discussions (FGD) said:

It has always been the work of the male members of the household to fence the gardens as a way of protecting them from invasion by wild and domestic animals. The men used tree logs and branches to fence the gardens. Men were also expected to do the ploughing of the irrigation fields. Women were the ones who were supposed to do the planting of the crops, weeding, watering, and harvesting. In some instances men would assist the women (Mr. Dzizangwe, Manyau Village).

The informal irrigators said that as the cash economy took root, men started migrating to towns, farms and mines in search of work, leaving the women in the villages. This created *de facto* women headed households, who became the sole managers of the irrigation gardens. Remittances from men helped to buttress agricultural activities in the gardens as they helped in the acquisition of inputs such as implements and seeds. Women were sole decision-makers, with regards to activities that had to be undertaken in the gardens. In some cases, men who would have retired from formal employment would occasionally help their wives in undertaking certain garden activities.

Men started to become more involved in informal irrigation as from the early 1990s, during the height of the economic reform programme, which saw most of them being retrenched from formal employment. This resulted in most of the men going back to the villages, and the only meaningful activity they could engage in to support their families was informal irrigation. This contributed to the transformation of the ownership of the gardens as having come onto the scene, men came and claimed a stake in the use and management of irrigation gardens.

Some of the men who were retrenched from formal employment remained in towns and joined the informal employment sector. The economic downturn witnessed in Zimbabwe between 2000 and 2009, forced a lot of people to move back to their villages of origins. Both the formally and informally employed were negatively affected. This significantly contributed to the return of most men in the Nyamubarawanda area. During this period, the Zimbabwe dollar became worthless as inflation soared to unimaginable levels. As a result, the majority of men opted out of employment and returned to the village to take up informal irrigation farming alongside their wives. A number of men across the three villages confirmed that they left town life between 2000 and 2009, to come and settle in Nyamubarawanda, and took up irrigation farming to sustain their families.

The women stated that the return of men to Nyamubarawanda meant that there had to be a redefinition of the ownership and operations of irrigation fields. Men began to play an active role in informal irrigation alongside women. As a result, they began to claim ownership of the gardens as well. Although in the majority of cases (44 per cent), women are regarded as the sole owners of the irrigation gardens, a significant percentage of men (32

per cent) have sole ownership of the gardens (Figure 3). In some households, men are regarded as the owners of the informal irrigation fields while in others, joint ownership prevails.

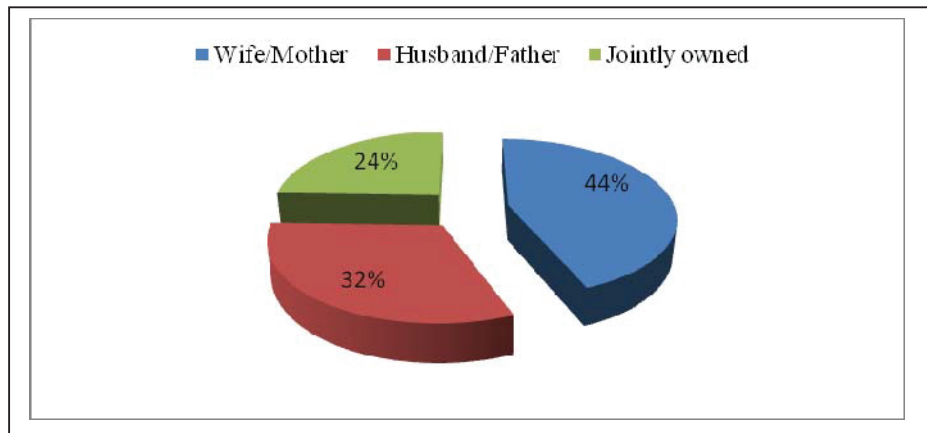


Figure 3: Ownership of Informal Irrigation Fields by Gender

Source: Study survey results

Most of the crops grown in the irrigation gardens are jointly owned by spouses. As noted earlier, the coming of men into mainstream informal irrigation influenced this ownership pattern. Traditionally, some of the produce, such as yams and sweet potatoes, were predominantly controlled by women. This ownership pattern became blurred as men became active participants in informal irrigation farming. The tendency is that once a particular crop is in demand, men want to have more control over that crop. Women argued that value crops, such as potatoes and beans, are mainly controlled by men throughout the production process, up to the marketing stage. Women who are heads of households are the only ones who have sole control of the informal irrigation activities.

However, men claim that they are now doing most of the work associated with informal irrigation, hence they have the right to own the produce. Most of those involved in informal irrigation highlighted the fact that in order to minimise conflicts in male-headed households, they have decided to accept joint ownership of the irrigation fields as well as the produce, and engage in joint decision-making regarding disposal of produce. Some women complained that their husbands have a tight grip on the produce, which compels wives to go as far as stealing the produce and selling it secretly. This gave credence to the fact that joint ownership does not always entail consensus in decision-making.

3.5 Contribution of Informal Irrigation to the Livelihoods of Households Involved

Crop production is an important lifeworld for actors involved, as it contributes to household food security. The practice of irrigation helps in ensuring that actors involved in this lifeworld harvest some crops for household consumption, especially in the context of water stress and scarcity (Rijsberman 2006). The study established that informal irrigation plays a pivotal role in the lives of the participants. All the households highlighted that informal irrigation is the cornerstone of their lives as they would not be able to live a comfortable life without practicing it. Households in the three villages mainly engage in informal irrigation, to grow crops to ensure household food security and to sell the surplus.

A variety of crops are grown in different irrigation gardens, throughout the year. In some instances, intercropping is common. Figure 4 highlights the commonly grown crops.

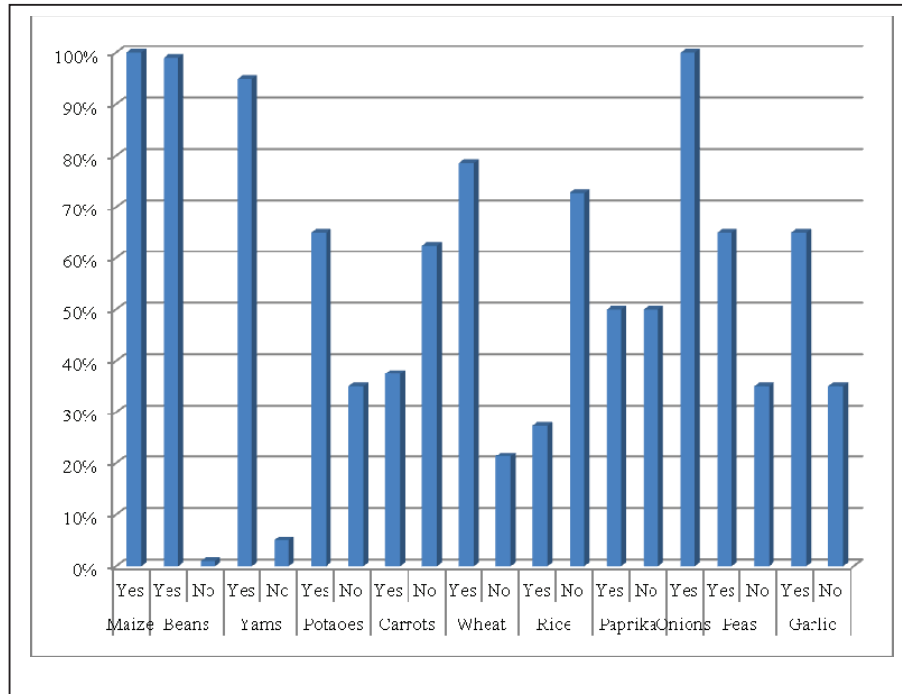


Figure 2: Commonly Grown Crops under Informal Irrigation

Source: Study survey results

The crops identified in Figure 4 are grown during different times of the year. All the households indicated that they have various crops, at any particular time of the year. Different crops and fruits are grown for various reasons. Firstly, to ensure that households have a balanced diet (58 per cent). Secondly, for sale (26 per cent), to generate income to purchase other basic necessities, such as sugar, salt and cooking oil, as well as to clothe children and send them to school. Thirdly, to avoid hunger (16 per cent). All the respondents, including those in focus group discussions, indicated that they had never experienced hunger within their households.

Harvests for the different types of crops depends on a number of factors, which includes size of the field or area planted and quantity of inputs such as fertilisers used. Most of the quantities given by the households were estimates as none of them kept strict records on how much would have been harvested. In most cases, crops are taken from the fields for consumption before they mature. This was particularly true for green mealies and different types of vegetables. The harvest range for selected crops is highlighted in Table 2.

Table 2. Crop harvest for selected crops

Crop	Harvest range
Maize	30 kg – 1000kg
Cabbages	15 kg – 150 heads
Sugar beans	100 kg – 700 kg
Yams	15 kg – 250 kg
Potatoes	10x15kg – 50x15 kg pockets
Wheat	15 kg – 500 kg

SOURCE: Study survey results

A greater percentage of what is consumed within the majority of the households comes from the irrigation fields. Consumption depends on what would be available during different times of the year. All the respondents indicated that they always have some food to consume from their irrigation fields. Eighty-five (85) per cent of what is consumed in the households comes from the irrigation fields. The majority of the households (70 per cent) said they were able to have three meals a day. The other 30 per cent stated that they have at least two meals a day, one late in the morning, and the other one in the evening. They explained that they do not cook in the afternoon, mainly because they were very busy in the irrigation fields.

The survey established that households involved in informal irrigation do not spend money on certain food items, mainly because they grow them in their gardens (Table 3). These food items included vegetables, bread (which was mainly substituted with yams and homemade wheat bread) and mealie meal. Informal irrigator households mainly spend money on food items such as cooking oil, salt, sugar, and tea leaves.

Table 3. Household expenditure on food items

Food item	Households spends money on these food items	
	Yes	No
Maize meal	6.1%	93.9%
Flour	82.6%	17.4%
Potatoes	21.2%	78.8%
Cooking oil	100.0%	0.0%
Tea leaves	93.0%	7.0%
Leafy vegetables	0.0%	100.0%
Onions	0.0%	100.0%
Tomatoes	10.0%	90.0%
Green mealies	0.0%	100.0%
Green beans	0.0%	100.0%
Yams	0.0%	100.0%
Sugar beans	0.0%	100.0%

SOURCE: Study survey results.

Although the different households spent some money on certain food items, they were not spending as much as they would, if they were not involved in informal irrigation. On average, each household spends US 40 per month to buy other food stuffs they do not produce in their gardens. The households reported that if they were not involved in informal irrigation, they would require more than US\$ 200 per month, to buy basic food stuffs. They pointed out that most of them would not have been able to raise this amount, given their levels of income.

None of the households had ever received food aid from the government or from donors. This is mainly because almost all the households had been able to feed themselves, even during periods when other areas were experiencing drought. Almost all the households pointed out that since they do not receive food aid, they would rather be assisted in being more effective in their farming activities. They pointed out that while others were being provided with food aid, they should be provided with agricultural inputs.

3.6 Marketing of Produce

Farming in general, and crop production, in particular, is used as an income generating activity, in order to assist the household to purchase non-agricultural products (Carletto 2007). Households first ensure that they have sufficient crops to consume, before they sell the surplus. In the absence of clear marketing structures, there is usually heterogeneity among the households in marketing strategies employed (Long and van der Ploeg 1992). Sixty-five per cent (65 per cent) of informal irrigators are involved

in the marketing of their crops. As shown in Figure 5, there is no significant different ($p = 0.729$) in marketing of crops across the three villages. Irrigators from all the three villages put some of the crops they grow on the market.

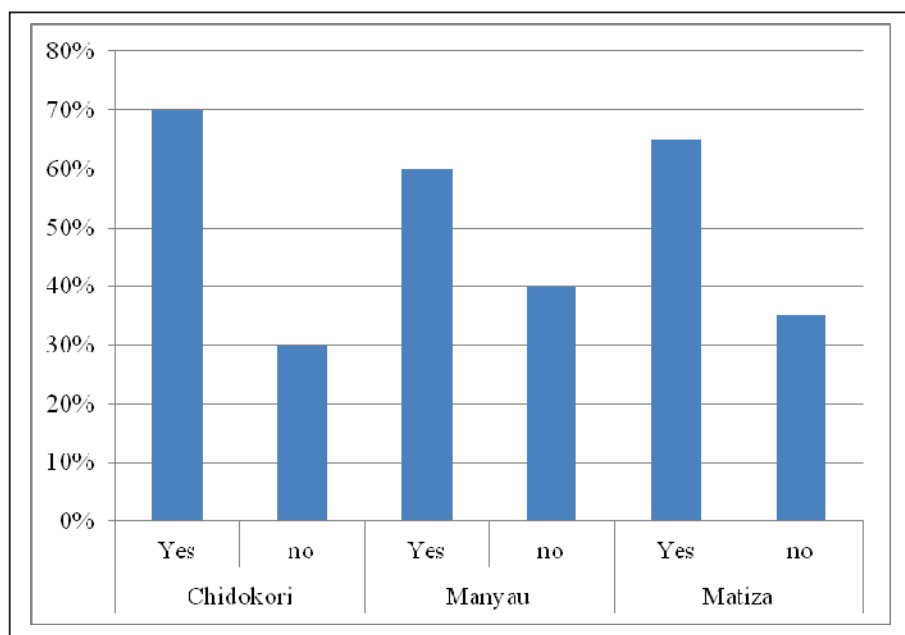


Figure 3: Marketing of Crops from Informal Irrigation Fields

Source: Study survey results

A wide range of crops are sold across the study sites, including green mealies, green vegetables, tomatoes, sugar beans, yams, and potatoes. A household that is involved in marketing of crops makes an average of US\$ 1,203.00 per year. The average amount earned by each household through marketing of produce is equivalent to what general workers in the formal and civil service sectors earn.

Informal irrigators have not yet been able to take farming as a business (Desmond and Siebert 2009). This can be attributed to lack of training and skills in sourcing for markets or in negotiating for contract farming deals. In most cases, crops are grown without a plan on where to sell the produce once harvested. Crops are sold to local homesteads (52.2 per cent), direct from the fields to buyers who come from outside Nyamaropa and further (16.4 per cent), in other villages within Nyamaropa (20.9 per cent), and outside Nyamaropa by the irrigators (10.5 per cent). The majority of the households cited transport as the main constraint to effective marketing.

They pointed out that transporting the produce to a place such as Nyanga requires a lot of money and time. Moreover, the Nyanga market is already flooded as farmers from other parts of Nyanga, with the same produce, converge here. Hence, most of the farmers prefer to sell their produce within the village. Others are building a customer base from major towns and cities, whom they communicate to whenever the produce is available. However, building a customer base requires one to offer competitive prices.

The fact that there is no proper marketing system amongst informal irrigators causes them to adopt haphazard marketing techniques, which ultimately do not ensure that they get adequate income. Although in some instances local actors can engage in actions that bring out their human agency, this has not been the case when it comes to produce marketing by informal irrigators in Nyamubarawanda. This partly explains why the majority (81 per cent) of households are facing marketing challenges. The challenges encountered include lack of markets (47.2 per cent), poor prices for produce (35.8 per cent) and lack of transport to take produce to markets (17 per cent). Produce such as tomatoes, cabbages and some leafy vegetables usually rot in the fields due to lack of markets. This problem exposes them to unscrupulous buyers from outside, who interface with them and determine the price. In most cases, households are left with no option but to barter their produce with foodstuffs such as cooking oil, sugar, and salt, and other products such as laundry soap. The irrigators term the process as literally giving away their produce for nothing.

3.7 Challenges in the Practice of Informal Irrigation Farming

A number of challenges are encountered by informal irrigators in all the villages studied. These include acquisition of inputs such as seeds and pesticides; unlined canals; water sharing problems; lack of markets for selling produce; garden protection, especially those whose gardens are not protected by fencing material; and crop diseases. The issue of inputs and unlined canals were highlighted as major challenges, which the farmers would like to have resolved.

Informal irrigation farmers recognise the need for the use of efficient water management methods that would help them to reduce on water loss. The farmers further indicated that they loose a lot of water through seepage, along their unlined canals. The farmers recommended lining of canals as this would reduce seepage while increasing the amount of water, for watering of crops.

It emerged that water distribution among farmers from Matiza and Chidokori is one of the major problems faced. The farmers have no agreed formula of water distribution. As a result, distribution is mainly on a first-come first-served basis or through negotiations that take place between the farmer currently irrigating and the one who would be irrigating next. This usually causes conflicts as most farmers would be in need of water at the same time. As earlier highlighted, farmers from across all the villages do

not have reliable markets to sell their crops. Consequently, most crops rot in the fields. In cases where farmers have buyers coming to buy their crops, buyers tend to dictate prices. The farmers highlighted that they would want a situation whereby they have a say in the determination of prices.

3.8 Anticipated Changes in Informal Irrigation Farming

Informal irrigators across the three villagers would like to see some changes in their irrigation activities, which would help them to undertake their farming in an effective manner. These changes include the use of modern farming and irrigation methods (70 per cent) that are not labour intensive. The farmers envisaged a situation whereby they would be using technology such as the drip system, sprinklers and small tractors. The adoption of modern farming techniques would enable the farmers to expand the area being farmed and enhance efficiency in farming practices. They would be able to irrigate some of their cropping fields that had been lying fallow for years. Irrigation pipes and pumps would be used to draw water from different water sources in the area.

The other change that the farmers would like to see relates to the affordability and availability of inputs (10 per cent) such as seeds, fertilisers and pesticides. The farmers would also like to see changes in the marketing of their crops (20 per cent). They envisage a situation whereby they will be able to negotiate better prices and be able to take their produce to different market places such as in Harare and Mutare. The farmers highlighted that they would appreciate undergoing some training in marketing, which would enable them to market their produce as a , to hotels and supermarkets around the country. They realised that they would be in a position to derive more benefits by selling their produce as a group rather than as individuals.

Almost all the farmers highlighted that the government was not playing a crucial role in their irrigation farming activities. This is mainly because the government regards their farming activity as illegal. As a result, there is very limited interface between the farmers and relevant government departments. Most of them are conscious of the fact that their type of irrigation was not recognised by the government. However, the farmers feel that the government is supposed to play a part in their farming activity since they are undertaking an activity that is enhancing self-reliance and ensuring food security, at the household level. Figure 6 highlights the various roles, which the informal irrigation farmers would like the central government to play, in enhancing informal irrigation.

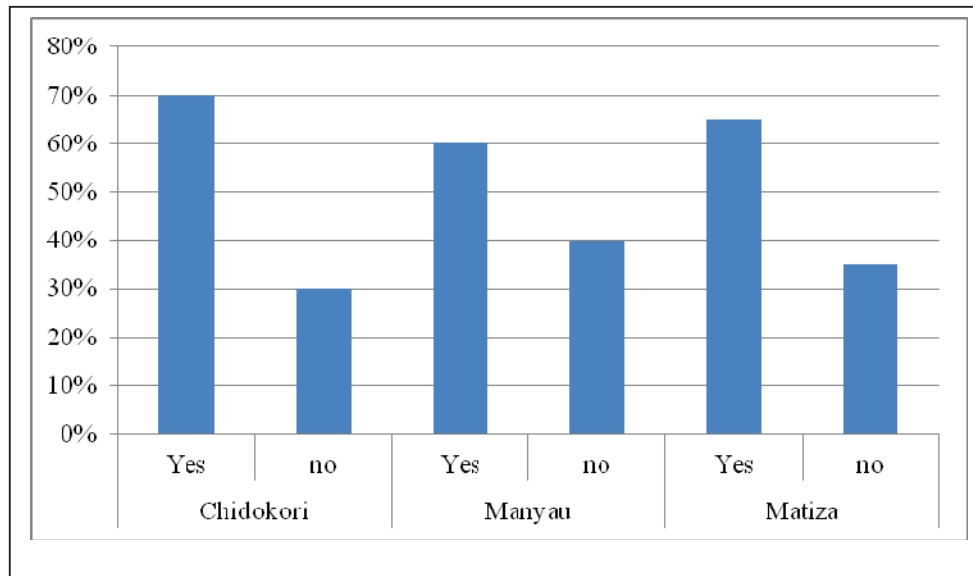


Figure 4: Roles which Central Government can Play in Informal Irrigation

Source: Study survey results

NGOs (94 per cent) are also seen as having a critical role to play in the development of informal irrigation. There has not been much assistance from NGOs for informal irrigation farming. The farmers realised that, the central government, which is currently cash strapped, might not be able to provide the assistance they require. They said NGOs could come in and play a critical role, to ensure the survival and sustainability of informal irrigation.

3.9 Sustainability of Informal Irrigation

The future and sustainability of informal irrigation in Nyamubarawanda and other areas mainly depends on water availability. Almost all the irrigators highlighted that water is critical as it allows them to grow various types of crops, throughout the year. Thirty-seven per cent (37 per cent) of the households revealed that water from their main sources for irrigation purposes has remained the same over the years. They attributed this mainly to constant rainfall and run-off in the area. Fifty-four per cent (54 per cent) of the households highlighted that water from their sources for informal irrigation had decreased over the years. The decrease in water from the two rivers that supply water for informal irrigation was attributed to changing climatic patterns. Other more religious members of the community attributed the decrease in rainfall to the abandoning of traditional rainmaking ceremonies, which were supposed to be held each year before the onset of the rains.

Though the majority of farmers said there has been a decrease of water for informal irrigation, almost all of them were of the view that the practice of informal irrigation has a bright future, especially if all the farmers could adopt efficient irrigation technologies, such as the use of sprinklers and if the canals are lined with cement, to reduce seepage. Informal irrigators actually foresee an increase in harvests. Most of the farmers said that the dollarization of the economy has enabled them to sell their produce in foreign currency. This has allowed some of them to purchase better irrigation farming technologies such as sprinklers and irrigation pipes. They all highlighted that they would not be abandoning informal irrigation as it enables them to feed themselves.

3.10 Factors that Can Strengthen Informal Irrigation

Several factors were identified as being crucial in strengthening informal irrigation, as highlighted in Figure 7. These include adequate rainfall and run-off in the Morozzi Catchment area, good water and land management practices, hardworking farmers, and better markets for crops.

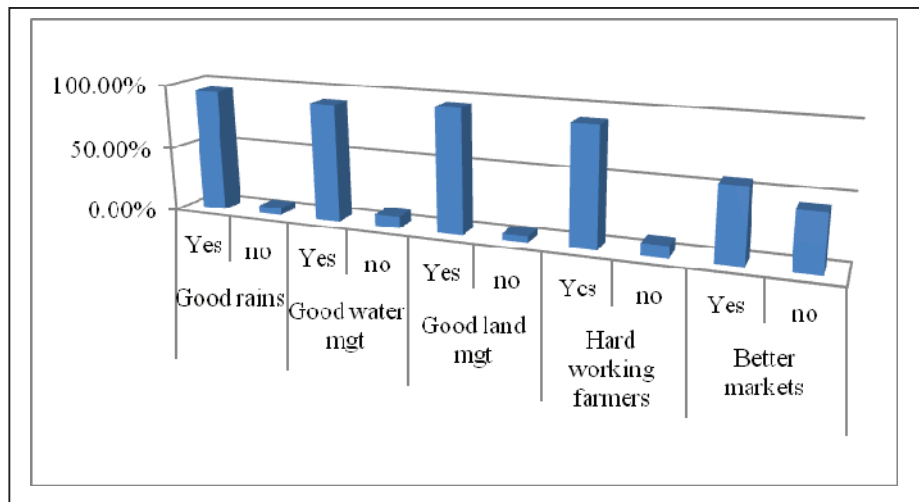


Figure 5: Strengths Associated with Informal Irrigation

Source: Study survey results

The farmers highlighted the fact that informal irrigation in Nyamubarawanda has survived for a decade or more, which is indicative of positive management practices that have been adopted and implemented. The informal water and land management has some positive aspects that have been crucial over the years. The management approach in informal irrigation is seen as being adaptive to change.

On the other hand, some factors identified by informal irrigators were seen as threatening their farming activities (Figure 8). These include the threat of decreased rainfall in future, increased number of people in need of informal irrigation plots, stream bank cultivation, unfavourable government laws, and poor land management practices. The farmers highlighted that climate change could actually cause less rain, which would have a negative effect on the amount of flow in the rivers, which supplied farmers with water.

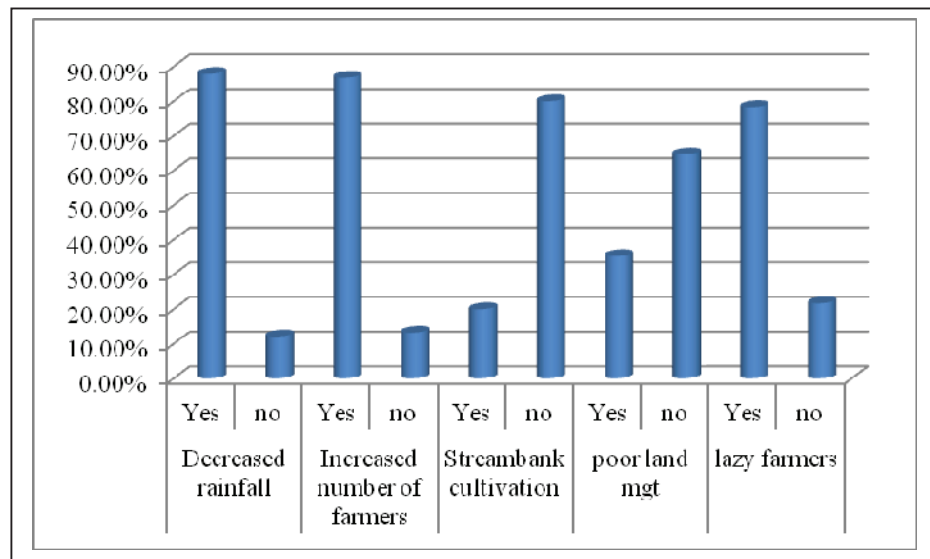


Figure 6: Threats to Informal Irrigation

Source: Study survey results

There is a strong concern among informal irrigators about the increasing number of households in need of irrigation plots, which are now difficult to acquire, especially in the cluster garden areas. Some of the new households are acquiring plots through their parents or through inheritance. However, some have failed to acquire fields, especially those without relatives who settled years ago.

4. Conclusion

Informal irrigation is practiced in different parts of the world, including Zimbabwe, where it has a long history dating back to the pre-colonial period. In Zimbabwe, this economic activity has survived different forms of legislation, aimed at stopping its practise. Despite the activity being branded as informal and illegal, it plays a critical role in enhancing livelihoods and food security among practising households. In some instances, informal irrigation has been able to put in place structures for

management of the systems, as is the case with the Manyau community in Nyamubarawanda.

Productivity and water efficiency under informal irrigation are greatly compromised by the use of traditional methods that use earthen canals and flood irrigation. Such irrigation methods need to be improved, to allow adoption of more efficient and effective methods. The government needs to give formal recognition to this economic activity, to facilitate improved irrigation practices. Dialogue is required as well as additional research that focuses on the potential of informal irrigation in national development.

Notes

1. The irrigation fields in all the villages are commonly referred to as gardens. This is because they are much smaller than the cropping fields and are irrigated just like gardens. The word garden is therefore used interchangeably with the word field

References

- Arce, A. and Norman, L. 2001. *The dynamics of knowledge interfaces between bureaucrats and peasants*. Wageningen: University of Wageningen.
- Adams. W. M. 1992. *Wasting the rains: Rivers people and planning in Africa*. London: Earthscan.
- Adams. W. M. and Andersen, D. M. 1988. Irrigation before development: Indigenous and induced change in agriculture and water management in Africa. *Journal of African Affairs*, 87 (3).
- Agritex. 1993. *Map of natural farming regions and farming areas of Manicaland Province*. Harare: Agriculture and Extension Services Department.
- Aguilar, L. 2007. Fact Sheet: *Gender and Climate Change*.
- Bolding, A. 2004. In hot water: *A study on sociotechnical intervention models and practices of water use in smallholder agriculture, Nyanyadzi catchment, Zimbabwe*. Wageningen: University of Wageningen.
- Bolding, A., Manzungu, E. and van Der Zaag, P. 1996. Farmer initiated irrigation furrows: Observations from the Eastern Highlands. In *The practice of smallholder irrigation: Case studies from Zimbabwe*, edited by E. Manzungu and van der Zaag. Harare: University of Zimbabwe, pp 191-218.
- Boserup, E. 2007. *Woman's role in economic development*. London: Earthscan.

- Carletto, G., Covarrubias, K., Davis, B., Krausova, M., Stamoulis, K., Winters, P., and Zezza, A. 2007. Rural income generating activities in developing countries: Re-assessing the evidence. *Journal of Agricultural and Development Economics*, 4 (1): 146-93.
- Carney, J. A and Carney, J. 2009. *A. Black rice: The African origins of rice cultivation in the Americas*. Harvard: Harvard University Press.
- CSO. 1998. *Poverty in Zimbabwe, Harare (based on income, consumption and expenditure survey 1995/96)*. Harare: Government Publications
- Central Statistical Office (CSO). 2012. *Census 2012: Preliminary results*. Harare. CSO.
- Cunliffe, R. N. 1998. *Natural resources and tourism within Nyanga District*. Harare: World Wide Fund for Nature.
- De Groot, R., van der Perk, J. and van Vliet, A. 2003. Importance and threat as determining factors for criticality of natural capital. *Ecological Economics*, 44: 187–204.
- Desmond, N. and Siebert, J. W. 2009. Toward better defining the field of agribusiness management. *International Food and Agribusiness Management Review*, 12 (4).
- Food and Agricultural Organisation (FAO). 2005. *Review of garden based production activities for food security in Zimbabwe*. A Study for the Food and Agriculture Organisation Working Group on Gardens Project. Harare: FAO.
- Gillingham, M. E. 1999. Gaining access to water: Formal and working rules of indigenous irrigation management on Mount Kilimanjaro, Tanzania. *Natural Resources Journal*, 39: 419.
- Joseph, H., Manjengwa., J. M. and Smart, T. 2013. *Zimbabwe takes back its land*. CT: Kumarian Press.
- Kujinga, K. (2010) *Impacts of Economic Reform Programme on local level rural institutions: Case studies of Nyanga and Gwanda rural districts*. Deutschland: Lambert Academic Publishers.
- Kujinga, K., Chingarande, S. D., Mugabe, P. and Nyelele, C. 2012. Interface between research, development and local actors in enhancing sustainable forest resources management: Lessons from Chimanimani District, Zimbabwe. *Journal of Social Development in Africa*, 27 (1): 23–56.
- Kujinga, K. 2003. *The impact of legislation on community based management of water for informal irrigation in Southern Africa: Case studies of Zimbabwe and Tanzania*. Commons Southern Africa Occasional Paper Series, No. 1/2003. Harare: Centre for Applied Social Sciences.
- Long, N. and van der Ploeg. 1994. Heterogeneity, actor and structure towards a reconstitution of the concept of structure. In *Rethinking social development*

theory, research and practice, edited by D. Booth. Essey: Longman.

- Long, N. 1992. From paradigm lost to paradigm regained? The case of an actor-oriented Sociology. In *Battlefields of knowledge: The interlocking of theory and practice in social research and development*, edited by A. Long and N. Long. London: Routledge.
- Long, N. and van Der Ploeg, J. D. 1989. *Demythologising planned intervention: An actor perspective*. Wageningen: Wageningen Agricultural University.
- Long, N. and Villarreal, M. 1994. The interweaving of knowledge and power in development. In *Beyond Farmer First*, edited by I. Scoons and J. Thompson. London: Intermediate Technology.
- Magadlela, D. 2000. *Irrigating lives: Development intervention and dynamics of social relationships in an irrigation project*. Wageningen: Wageningen University.
- Magadlela, D. and Hebnick, P. 1995. Dry fields and spirits in trees: A social analysis of development intervention in Nyamaropa communal area in Zimbabwe. *Zambezia*, 22 (1): 43–62.
- Manzungu, E. 2001. A lost opportunity of the water reform debate in the fourth parliament of Zimbabwe. *Zambezia*, 28 (1): 97-120.
- Manzungu, E. and Zaag, P. 1996. *The practice of smallholder irrigation: Case studies from Zimbabwe*. Harare: University of Zimbabwe.
- Mompoti, B. N., and Peter, T. J. 2009. The contribution of subsistence farming to food security in South Africa. *Agrekon*, 48 (4): 459-482.
- Motsholapheko, M. R., van der Post, C. and Kgathi, D. L. 2012. Rural livelihoods and household adaptation to desiccation in the Okavango Delta, Botswana. *Journal of Water and Climate Change*, 3 (4): 300–316.
- Perreault, T. A., Bebbington, A. J. and Carroll, T. F. 1998. Indigenous irrigation organizations and the formation of social capital in Northern Highlands, Ecuador. *Conference of Latin Americanist Geographers*, 24: 1-15.
- Rijsberman, F. R. 2006. Water scarcity: Fact or fiction? *Agricultural Water Management*, 80 (1): 5-22.
- Seur, H. 1992. *Sowing the good seed: Intervening of agricultural change and religion in Shanje District of Zambia*. Wargeningen: Wageningen University.
- Surveyor General. 1984. *Zimbabwe 1: 1,000,000 Natural regions and farming areas*. Harare: Ministry of Lands and Agriculture and Rural Resettlement.
- Svubure, O., Ahlers, R. and van Der Zaag, P. 2006. *Local level participation in smallholder formal and informal irrigation and the water sector reforms in Zimbabwe*. Chinhoyi: Chinhoyi University of Technology.

- Ubels, J. 1989. Irrigation systems as a social interface: Toward an understanding of irrigation development as an interactional process. In *Encounters at the interface: The social discontinuities in rural development*, edited by N. Long. Wageningen: Wageningen Agricultural University.
- Underhill, H. (1990). *Small-Scale irrigation in Africa: The context of rural development*. Bedford: Granfield Press.
- van der Linde, H., Oglerthorpe, J., Sandwith, T., Snelson, D. and Tessemay, Y. 2001. *Beyond boundaries: Transboundary natural resources management in Sub-Saharan Africa*. Washington, D.C: Biodiversity Support Programme.
- Watson, E. E., Adams, W. M. and Mutiso, S. K. 1998. Indigenous irrigation, agriculture and development, Marakwet, Kenya. *The Geographical Journal*, 164 (1): 67-84.
- Yabes, G. (1992). The Zanjeras and ILocos Norte irrigation Project: Lessons of environmental sustainability from The Philippines traditional resource management system. In *Grassroots, environmental action: People's participation in sustainable development*, edited by D. Ghai and J. M. Vivian. London: Routledge.
- Zacchini, M., Pietrini, F., Mugnozza, G. S., Iori, V., Pietrosanti, L. and Massacci, A. 2009. Metal tolerance, accumulation and translocation in poplar and willow clones treated with cadmium in hydroponics. *Water, Air, and Soil Pollution*, 197 (1-4): 23-34.

Innovative but Not Feasible:
Green Water Saving Schemes at the Crossroad in Semi-Arid Lands
of Kenya

Chris Allan Shisanya, Cush Ngondo Luwes and Joy Apiyo Obando

Abstract :

Green Water Saving (GWS) schemes are very crucial in determining the availability of blue water in streams, lakes and groundwater. Green water is being depleted in Kenya due to the effects of deforestation and climate change. This study assessed the bio-physical need, sociopolitical acceptability and economic feasibility of these schemes in Muooni and Ngusishi catchments. Statistical trend analysis for selected hydro-climatic variables, spatial models for land use and land cover change, hydro-economic model for cost recovery and efficiency inventory, benefit-cost analysis, and contingent valuation satisfactorily proved that GWS schemes are innovative and biophysically needed but not economically viable in semi-arid Kenya.

1. Introduction

1.1 Background

Agricultural production in most tropical arid and semi-arid lands (ASALs) is significantly affected by changing weather patterns, possibly due to human-induced activities and other anthropogenic factors (Downing 2003). In most African ASALs, rainfed agriculture has become highly vulnerable to climate change and deforestation, which are increasingly depleting the little “blue water” available in springs, streams, lakes, and groundwater. Climate change has triggered desertification and water crises in the ASALs by increasing evapo-transpiration, thus resulting in three possible outcomes: (i) Too little water; (ii) Too much water; (iii) Very dirty water (Förch et al. 2005). Moreover, uncontrolled population and economic growth exacerbate “water poverty”, which is said to be a materialization of “green water” depletion arising from large-scale deforestation (Clarke and King 2004; Bates et al. 2008). This plant-water crisis is the major cause of agricultural inefficiency, food insecurity and poverty in Kenyan ASALs (Oduol et al. 2006; Luwesi 2010; Scherr et al. 2011). Hence, there is need for agricultural water development, for food security and poverty alleviation in rural Kenya.

As “business-as-usual”, policy intervention toward solving water crises has usually been translated by increased investments in dams and water tanks, to save blue water. The use of inter-basin transfer, rationing and regulation of water vendors’ prices in times of drought as well as climate information systems and early warning systems have also shaped the thinking of policy-

makers in the water sector (Reisner 1993; Subramanian 2001). Yet, blue water actually represents 1/3 of the total rainwater in the soil, the remaining 2/3 being found in grasslands, woodlands (forests), marshlands, farms (crops), arid land cover, and other land cover types representing the reservoir of green water (Rockström 2003). Consequently, the implementation of “Green Water Saving” (GWS) schemes is likely to be an innovative approach toward enhancing sustainability in water resource management through co-operation between upstream and downstream stakeholders in a “Payment for Environmental Services” (PES) scheme (Malesu et al. 2007; Luwesi et al. 2012).

Grieg-Gran et al. (2006) note that a PES scheme encompasses various Environmental Services (ES), which include watershed services, carbon sequestration, biodiversity conservation, and landscape beauty. A PES scheme that is implemented within the limits of a catchment area and for the sole purpose of rewarding watershed services is virtually a “Payment for Watershed Services” (PWS) or a “Green Water Credit” (GWC) scheme. These schemes involve market mechanisms to pay, reward or compensate upstream and midstream landowners, to incentivize them to maintain the catchment or modify a particular land use that was affecting the availability and/or quality of water resources downstream (Ortega-Pacheco et al. 2009). The schemes have been successfully tested globally and found to be practically effective, biophysically possible, socially acceptable, and economically feasible (Dent and Kauffman 2007). They are flexible and farmer-friendly investments on “Soil and Water Conservation” (SWC) measures and have the potential of increasing the accessible “blue water” in streams and lakes as well as groundwater, by at least 50 per cent through increased water table and ultimately, extensive surface runoff (Kauffman et al. 2007).

1.2 Problem Statement

Most small-scale farmers living in the Kenyan ASALs incur losses due to their high vulnerability to drought. This is related to the fact that there is minimal stored water per capita and when severe droughts occur, water storage areas are rapidly drawn (Mumma et al. 2011). Consequently, there is great need for investment in agricultural water development in the ASALs of Kenya. These investments require cheap and effective innovations for harvesting and saving water, including rainwater, to “climate-proof” some communities, especially by providing water to those who do not have easy access. But, how would rural communities venture in saving sufficient farming water under changing climatic conditions? “The great challenge we face is to get to business-not-as-usual” to enhance green water storage (Berntell 2008: 1-2). GWS schemes are likely to be the most reliable, renewable and drought resistant water sources since they involve all stakeholders in the quest for innovative ways to sustain green water resources in the catchment. Yet, many catchment managers neither recognize their performance nor do they reward their outcomes in most

ASALs, the Kenyan ones included (Geertsma et al. 2010; Hoff et al. 2010; Immerzeel et al. 2010; Wilschut 2010). Why would policy implementers queasily defer or practically reject such positive and cheap remedies for water crises? Are GWS schemes bio-physically needed and socially and politically accepted in Kenyan ASALs? To what extent are they economically viable? These questions are elicited in this study.

1.3 Methodology

This study adopted a robust “Performance Assessment and Evaluation” (PAE) implemented within the framework of quasi-experimental design, to assess farmers’ vulnerability to water disasters and their innovativeness in curbing drought and flood in Muooni Catchment (experimental group) and Ngusishi Catchment (control group), in the eastern region of Kenya. It intended to appraise the efficiency, cost recovery ability and financial affordability of GWS schemes, were they found to be innovative by farmers, for curbing drought and/or flood. Empirical tools of scientific research included a social survey involving 66 and 106 farmers from Muooni and Ngusishi catchments, respectively; 15 in-depth interviews and one focus group discussion conducted in each catchment; hydro-geomorphologic field surveys; and an extensive literature review. Time series forecast (from 1965 to 2030) involved the determination of selected hydro-climatic trends and water balance, using SPSS and MS Excel spreadsheets as well as the Water Evaluation And Planning (WEAP) tool. Spatial models for Land Use and Land Cover Change (LULCC) were also employed and processed via ILWIS and ArcGIS software. Other analytical tools included Hydro-Geomorphologic and Economic Risk Assessment and Management (HERAM), Vulnerability-Capability Assessment (VCA+), Performance-Based Management Rating (PMR), hydro-economic Cost Efficiency Inventory (CEI), Benefit-Cost Analysis (BCA), and Contingent Valuation Methods (CVM).

1.4 Organization of the Paper

Following the introduction, a literature review builds on existing scholarly works on GWS schemes, to streamline a robust PAE for GWS schemes. This is followed by a brief presentation of the study area to unveil factors hindering the adoption of GWS schemes in the selected catchments. Key results and discussions are aligned as follows: (i) Farmers’ vulnerability to water disasters; (ii) Innovative farming water saving strategies; (iii) Performance rating of water institutions for saving green water; (iv) GWS schemes’ economic efficiency and financial affordability. Finally, the conclusion presents a synthesis of main findings and recommendations are made, based on the study.

2. Literature Review

This study provides a robust methodology for assessing and evaluating the performance of GWS schemes in the ASALs in the course of climate

change. It is based on a Biophysical Needs Assessment (BNA), a Socio-Political Acceptability Appraisal (SPAA) and Economic Viability Study (EVS). Prior to presenting the robust PAE, an analytical description of the possible causes of farmers' vulnerability to water disasters is provided along with some innovative solutions initiated by farmers to curb drought.

2.1 Farmers' Vulnerability to Water Disasters

The unsound management of land and water resources available within the catchment area is the major cause of farmers' vulnerability to water disasters in the ASALs (Cosgrove and Rijsberman 2000). This relationship between the management of water and that of land resources is often the centre of discussions at local catchment, national landscape and regional basin scales, to determine the quantity and quality of water infiltration in the soil. Thus, the water cycle is intrinsically linked to Land-Use/ Land Cover Change (LULCC) so that any decision on water allocation and conservation in the catchment becomes a land use decision (Legesse et al. 2003; Falkenmark and Rockström 2004). Owing to the fact that Kenya is mostly covered by grasslands, forests and other types of woodlands, most hydrologists believe that the available rainfall can afford to supply water six to seven times the Kenyan population (Terer 2004; Mogaka et al. 2006). They assert that the apparent little endowment in surface water in ASALs is actually not the main cause of farmers' vulnerability to water shortages in Kenya. Instead, the failure by the government to develop other water sources besides surface water resources exacerbates the country's vulnerability under the impact of climate change (Ngigi et al. 2005; Mumma et al. 2011). It is actually policy-makers' inability to fully invest in "green water saving" (for plant water use), that has precipitated the vulnerability of marginal communities to drought (UNEP 2011). Most interventions in the ASALs of Kenya are focused on "blue water saving" to supply surface and groundwater, without involving local communities in the management process, directly and wholly. This explains why the designed dams, boreholes and water allocation plans have failed. Therefore, water policy-makers in Kenya should focus on the effectiveness of policy interventions, to reduce the vulnerability of the population to drought.

2.2 Farming Water-Saving Strategies in Drought Stricken Areas

In light of the broken public-private partnership experienced in rural Kenya, most farmers have resolved to rely on traditional water conservation practices. Regrettably, less innovation takes place to mitigate the effects of water shortage and sustain community livelihoods in the course of climate change (Shakya 2001; van Aalst 2006; Sehring 2008). Yet, Subramanian (2001) indicates that developed countries have resolved water problems only through reservoir storage at different stages of the river flow. So, if water shortage problems are solved more quickly in the ASALs of India rather than humid regions, it is simply because of adaptation of traditional water storage systems to drought, mainly using deep ponds, storage wells and underground tanks. This is likely not to be

the case in Kenya. Shisanya (2005), for instance, observed that about 58 per cent of people living in rural Western Kenya, and more precisely the Kakamega area, have to face serious challenges related to portable water accessibility during drought. This is especially attributed to lack of technical know-how, especially where boreholes are found, and inadequate means of transport and finances for assuring permanent water supply. These factors increase socioeconomic externalities that impact directly on the maintenance of the catchment environment. However, Tiffen et al. (1994) demonstrated how local communities in Machakos District of Kenya ensured environmental stability and survival of agricultural land use during drought, through effective SWC measures. This skillful use of indigenous knowledge enabled them to cope with increasing population pressure on land resources. Thus, a careful application of SWC techniques is a key to successful adaptation to environmental changes. Likewise, Cheserek (2005) lauded some populations of the Rift Valley of Kenya for upholding traditional SWC measures to cope with drought. For instance, the Marakwet agro-pastoralists use traditional SWC strategies to protect their water courses against drought and mitigate subsequent conflicts over the little resources available, through equitable allocation plans.

From the analytical description, it is clear that there are two main schools of thought arising from investment in water savings, namely “Blue Water Supply” (BWS) projects on one end, and “Green Water Saving” (GWS) schemes, on the other. Typical BWS projects involve the construction of dams and ground tanks within major catchment areas and the drilling of boreholes to tap groundwater, which are *primum non nocere* (Ledec and Quintero 2003; World Bank et al. 2008). However, investments in GWS schemes mainly compound investments in the people and ecological systems that depend on the availability and quality of water resources and its temporal distribution (Huggins 2002; Gleditsch et al. 2004). These schemes are mainly implemented through institutionalization of SWC measures and pro-poor schemes implemented within the PES framework (Ragab and Hamdy 2004; Malesu et al. 2007; Reij et al. 2009; Ortega-Pacheco et al. 2009; Luwesi et al. 2012). These mechanisms involve close cooperation between upstream and downstream farmers, those upstream being green water services’ “sellers” and their downstream counterparts being “buyers” (Wunder 2007).

Hessel et al. (2003), Hoff et al. (2007) and Hunink et al. (2010) demonstrate that Green Water Credits (GWCs) are biophysically and technologically effective when it comes to controlling soil erosion and increasing soil moisture. Similar schemes have also been implemented in countries and regions such as Australia, Southeast Asia, West Africa, South Africa, and East Africa, to address the ever widening gap between water demand and supply (Mukheibir 2008; Islam et al. 2010; Zhang et al. 2010; Al-Salaymeh et al. 2011; Nyongesa and Muigai 2012). But how environmentally friendly, socially acceptable and economically viable are these schemes in the eastern region of Kenya? The following sub-sections

present scholarly approaches towards assessing the non-use value of GWS schemes in farming and evaluating the performance of water institutions.

2.3 Bio-Physical Needs Assessment of GWS Schemes

Vulnerability to water disasters and farmers' coping strategies, annotated above, were indicators of the need for implementing GWS schemes in the ASALs. However, a thorough BNA necessitates meteorological, hydrological and other geospatial models to assess the biophysical need of GWS schemes. These may include statistical forecast models, Soil and Water Assessment Tool (SWAT), Water Evaluation and Planning (WEAP) tool, Remote Sensing and GIS, to name but a few (Luwesi and Bader 2012). For instance, Hessel et al. (2003) used Limburg Soil Erosion Model (LISEM) to simulate the effects of land use and management strategies for reducing runoff and erosion rates in the Danangou Catchment, in the Loess Plateau of China. The study found decreases in runoff and soil erosion of about 5 to 15 per cent, after implementing improved SWC measures from the existing land use pattern. Moreover, there was a decrease of 40 to 50 per cent discharge and 50 to 60 per cent soil loss under changing land use patterns as the slope steepness decreased. Similarly, Liu et al. (2003) simulated the impact of climate change and LULCC on runoff in the Yellow River, for the period 1980–1990, using the SWAT model. Their findings show that an increase of 1°C in temperature resulted in decreased runoff of 109 per cent, while land use change increased runoff by 10 per cent in the source catchment of the Yellow River. These results indicate that GWS schemes have a real non-use value in terms of soil and water conservation in the catchment (Luwesi et al. 2011).

2.4 Performance and Social Acceptability of GWS Schemes

Rockström et al. (2009) suggest that local communities should exert strenuous efforts to accrue investments in drought resistant, flexible and farmer-friendly SWC measures that are channelled through institutional, legal and policy frameworks, to strengthen the existing schemes. The assessment of such Performance-Based Management (PM) necessitates meeting the conventional “Three Es”, namely: (i) *Economy* of their inputs; (ii) *Efficiency* of their outputs; (iii) *Effectiveness* of their impact (Mcgill 2006). The PM is a process that aims at yielding infrastructure and services that are economically viable and efficient, to effectively address the core values of institutional sustainability, namely environmental soundness, economic profitability, social equity, transparency, and accountability for resource management (Huggins 2002; Kasambala et al. 2006; Ngigi and Macharia 2007). In general, a PAE is needed to monitor and evaluate, consistently and regularly, GWS schemes based on their individual performances. However, when dealing with a catchment management in the context of a consolidated GWS scheme, a robust PAE is used for monitoring and evaluation. The latter uses a sociological approach to hypothesize basin-wide or regional impact of policy intervention, without isolating specific inputs of individual GWS schemes. This enables the

measurement of gaps and trends leading to the environmental need, social acceptability, and economic viability of GWS schemes and related water management institutions from a “vantage view” (Savenije and van der Zaag 2002). Rogers (2005) and Kazbekov et al. (2009) used such an approach to construct effectiveness-based metrics for Community Water Management Systems (CWMS) based in larger basins of the USA and the Water Users’ Associations (WUAs) operating in Osh Province of Kyrgyzstan, respectively, to objectively quantify their ability to deliver efficiency-based water infrastructure and services. In this study, a different PAE system is used to inform on the “*capability*” of water management institutions in Kenya to attain the goals of the water sector reforms through implementation of GWS schemes. This will assist policy-makers to adjust their regulations to enhance the efficiency and effectiveness of GWS schemes.

2.5 Economic Efficiency and Financial Sustainability of GWS Schemes

A GWS scheme has to meet basic requirements to acquire sufficient financial resources and minimize productive and distributive inefficiencies in agriculture (Stephenson 2005; Meijerink et al. 2007). Enhanced allocative, scale, technological, and cost efficiency measures assures the scheme of full cost recovery. Typically, traditional approaches were used to inform the costs and revenues as well as the Benefit-Cost Ratio (BCR) resulting from discounted values of any investment, and which determine the status of economic efficiency (OAS 1991; Anandajayasekeram 2004; DFT 2011). Yet, this is fairly true if carried out under a normal economic scenario, where market prices are stable, fair competition prevails and a proper sensitivity analysis is provided. In the course of climate change, traditional methods can easily be challenged due to unpredicted environmental changes (Brown 2001; Hulme et al. 2001; Jones et al. 2004; Smyth et al. 2004; Steinemann et al. 2005; Stern 2007). Therefore, such modeling will require randomization to take into account probabilistic effects of environmental disasters (López-Baldovín et al. 2006; Oduol et al. 2006; Barah 2009). Owing to the fact that probabilistic models for green water supply and demand are yet to be revealed by scientists, nonconventional methods for cost-efficiency, cost-effectiveness and benefit-cost analysis are used in this study to unveil the economic efficiency, effectiveness and benefit-cost ratio of GWS schemes. It is in favour of such an extended economic valuation that Rietbergen-McCracken and Abaza (2000) and Venkatachalam (2003) proposed a compendium of techniques that integrate both internal and external environmental costs and benefits, to value sustainable management of natural resources as well as Contingent Valuation Methods (CVM). However, these “extended” benefit/cost valuation methods pay little attention to the economic efficiency and effectiveness of “non-market” projects such as GWS schemes. Consequently, this study first conducted a hydro-economic Cost-Efficiency Inventory (CEI) prior to revealing the BCR of GWS schemes,

using an extended Benefit-Cost Analysis (BCA) and a Contingent Valuation Methods (CVM) under assumption of normality, drought and flood (Luwesi 2010; Luwesi et al. 2012). The CEI and BCA were based on financial mathematical models using linear programming, which are embedded in the WEAP system. The CVM totally relied on a non-probabilistic prediction of downstream farmers' Willingness To Pay (WTP) and upstream farmers' Willingness To Accept (WTA) compensation for GWS services. Individual WTP and WTA bids were consolidated at catchment level to unveil the schemes' ability for cost recovery.

3. Findings and Discussion

3.1 Presentation of the Study Area

Results presented in this study are mainly drawn from fieldwork conducted in Ngusishi and Muooni catchments, in the eastern region of Kenya. These two catchments were purposely selected to build scenarios of vulnerability/capability to water disasters (floods and droughts) in the ASALs of Kenya. Ngusishi Catchment is located in Mutarakwa Sub-Location, Ngusishi Location, Timau Division of Meru County (within the former Imenti North District of Eastern Province of Kenya). Its area is estimated to be 45.8 square kilometers (km^2) and it is bound by longitudes $37^\circ 10' 30''$ E and $37^\circ 20' 24''$ E, and latitudes $0^\circ 08' 03''$ N and $0^\circ 20' 05''$ N. Hydrologically, Ngusishi is a sub-catchment of Timau Catchment, which belongs to the great Ewaso-N'giro Basin that lies within the ASALs of Kenya. It is a haven to 5,049 people distributed across 1,685 households, with a total density of 110 persons/ km^2 . Muooni Catchment, on the other side, is inhabited by about 24,000 people distributed within 4,539 households, thus making an average population density of 960 persons/ km^2 . The latter belongs to the eastern highlands arc and is part of the Athi River Basin. It is bound by latitudes $1^\circ 14' 24''$ S and $1^\circ 16' 48''$ S, and longitudes $37^\circ 9' 36''$ E and $37^\circ 12'$ E. It is located in Kathiani Division of Machakos County. The latter is well known for its recurrent episodes of drought and famine, reported since the 19th century (Jaetzold et al. 2007; KNBS 2010; Luwesi 2010).

3.2 Farmers' Vulnerability to Water Disasters

Results of the Vulnerability-Capability Assessment (VCA) indicate that farmers in the ASALs of Kenya are more vulnerable to drought than flood. This is mostly explained by the warming micro-climatic patterns, inconsistent land use activities with SWC and environmental degradation, leading to the depletion of water resources in the catchment.

3.2.1 *Micro-Climate Warming*

The forecast of expected mean temperatures in Ngusishi Catchment reveal increases of 1.6°C in a century ($R^2 = 0.84$), which will be accompanied by increased annual rainfall of about 15 mm per century, and decreased river discharge of 0.7 per cent downstream ($R^2 = 0.835$). Muooni Catchment, in

turn, will experience an increase of about 1.2 °C of mean temperatures per century ($R^2 = 0.863$) with subsequent decreases in mean rainfall of about 10 mm per century ($R^2 = 0.877$) and decreased river discharge of 1.2 per cent downstream ($R^2 = 0.667$). Table 1 summarizes these results.

Table 1. Forecast of seasonal hydro-climatic variables in the selected catchments¹

Statistics	Ngusishi			Muooni		
	Temp [°C]	Prec [mm]	Disch [m ³ /s]	Temp [°C]	Prec [mm]	Disch [m ³ /s]
SARIMA	(102)(011)	(003)(011)	(013)(011)	(003)(011)	(002)(101)	(102)(011)
Constant (a)	26.759	138.919	2.166	22.05	55.553	6.657
Estimate (b)	0.004	0.035	-0.007	0.003	-0.029	-0.012
SE (a)	0.014	0.11	0.020	0.003	0.289	0.314
SE (b)	0.000	0.001	0.000	0.0007	0.064	0.065
t stat (a)	3.002	3.001	142.613	61.383	79.643	7.176
t stat (b)	28.060	28.257	-27.711	9.078	-3.355	-4.795
Sig. (a)	0.000	0.000	0.000	0.000	0.000	0.000
Sig. (a)	0.000	0.000	0.000	0.000	0.000	0.000
MAPE	1.524	22.753	44.624	2.131	27.97	39.14
ACF	0.026	0.040	-0.128	-0.27	0.23	-0.025
R ²	0.840	0.842	0.837	0.863	0.863	0.667

Notes: ¹ Forecast per quarter in Ngusishi and Muooni

SOURCE: Fieldwork (Shisanya and Luwesi 2012)

The above table shows increasing trends of seasonal temperatures accompanied by subsequent decreasing trends of seasonal discharges while seasonal rainfall is expected to decrease in Muooni and increase in Ngusishi. This forecast was accurately depicted by Hulme et al. (2001) in their projections of the African climates for 1900–2100. The latter confirm increased future temperatures across Africa of 0.2–0.5°C per decade for the lowest SRES scenario (B1) and the highest one (A2), respectively, along with undefined changes in seasonal rainfall. Nonetheless, the warming would be greater in the semi-arid margins of the Sahara and central-southern parts of Africa rather than in the northern parts and the equator. Also, annual rainfall would generally be expected to increase across Africa. Mumma et al. (2011) associate this micro-climate change with the global warming, sea surface temperature rise, ocean currents, and atmospheric winds occurring in the southern hemisphere, known as El Niño and La Niña.

3.2.2 Inconsistent Land Use Activities

The assessment of “Land-Use/ Land Cover Change” (LULCC) clearly emphasized a drastic depletion of natural vegetations, shrubland, grassland and riverine vegetation of about 62 per cent in Ngusishi Catchment (from

2,324.83 hectares in 1976 to 883.7 hectares in 2007), whereas the analysis of satellite images for a similar period revealed a re-greening of Muooni Catchment of about 19.4 per cent (from 1,191.65 hectares in 1976 to 1,422.99 hectares in 2010) (Figure 1). This re-greening was mainly explained by the effects of agroforestry within a man-made forest looking like a “natural forest” from this vantage view (Figure 1).

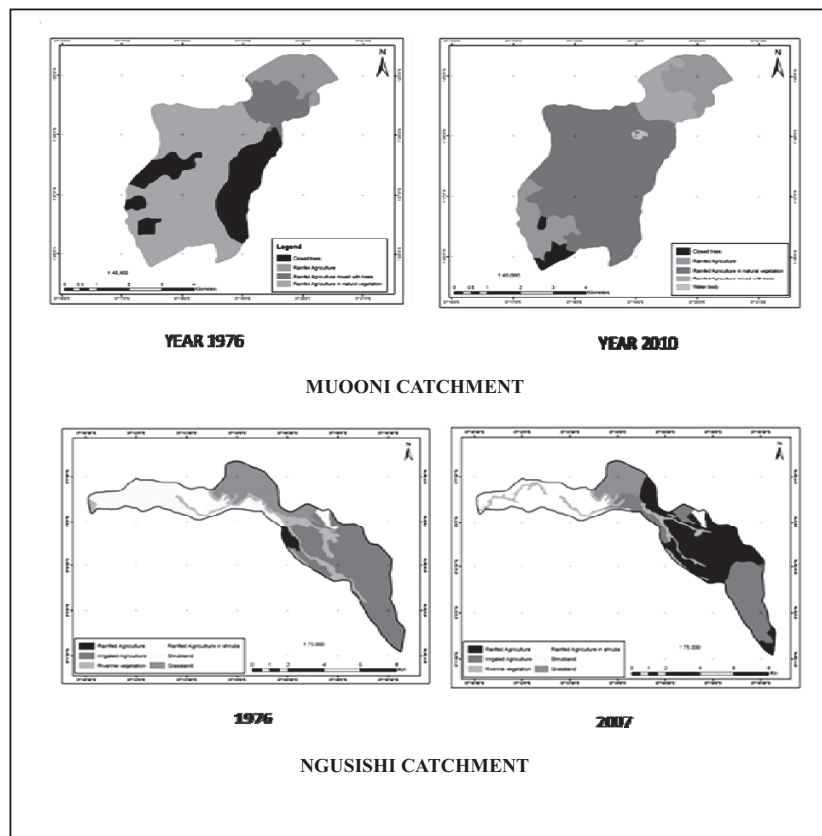


Figure 1: Land-Use/ Cover Change in Selected Catchment Areas of Kenya (1976-2007).

(Analysis by Shisanya and Luwesi (2012) based on Landsat images from DSRSS).

Tiffen and Mortimore (2002) witnessed this fact in 1994 during the analysis of aerial photographs from the former Machakos District. They explain, “Contrary to expectations, aerial photos suggest that the District [of Machakos] has become more, not less, wooded since the 1930s. Small-scale tree planting efforts have been beneficial; farmers plant trees to

stabilize soils and supply fruits and timber. Akamba also minimize deforestation by using dead wood, farm trash, and hedge clippings for firewood.” Yet, the threat of unfriendly exotic trees on the sustainability of water resources and agriculture resilience in such ecosystems was decried by 54.4 per cent and 8.6 per cent of farmers living in Muooni and Ngusishi, respectively, especially with regard to eucalyptus tree planting (33 per cent) and grevilia tree planting (14.3 per cent) in Muooni Catchment. The planting of eucalyptus trees along the riverines and within the wetlands is among the malpractices reprobated by scientists, and which needs to be addressed in the management of farming water in the Kenyan ASALs. This land use malpractice is inconsistent with soil and water conservation in the catchment because it is a major emulator of water stress and scarcity in the ASALs (Kitissou 2004; Ojwang 2008; Ngonzo et al. 2010). Nonetheless, in line with the Kenya Vision 2030, farmers living in the ASALs are sensitized to embrace crop selection and specialization (to 2 or 3 crops per plot), to avoid planting crop species that are water unfriendly within the catchment area (KNBS 2007). A strong recommendation was made regarding eucalyptus *grandis*, which matures in less than three years and over-abstracts water during cropping and growth stages.

3.2.3 Water Resource Depletion

The prediction of the total water balance in 2010 shows a surplus of 1,007.14 m³/day in Muooni while Ngusishi recorded a total deficit of 27,760.59 m³/day in 2010 (Table 2).

Table 2. Computed water demand and balance in the study areas in 2010

Variable	Ngusishi	Muooni
Total Water Demand	41,084.045 m ³ /day	26,752.470 m ³ /day
Upstream:	32,579.615 m ³ /day	10,272.949 m ³ /day
Downstream	8,504.400 m ³ /day	16,479.521 m ³ /day
Domestic/ Institutional Demand	2,260.15 m ³ /day	1,504.030 m ³ /day
Schools	-	230.380 m ³ /day
Health Centres	32.50 m ³ /day	87.500 m ³ /day
Water Projects	2,201.65 m ³ /day	996.150 m ³ /day
Factories	26.00 m ³ /day	190.000 m ³ /day
Livestock Demand	65.005 m ³ /day	340.272 m ³ /day
Upstream:	29.252 m ³ /day	153.122 m ³ /day
Downstream	35.753 m ³ /day	187.150 m ³ /day
Agricultural Demand	38,758.89 m ³ /day	23,404.140 m ³ /day
Upstream:	30,735.80 m ³ /day	8,987.190 m ³ /day
Downstream	8,023.09 m ³ /day	14,416.950 m ³ /day
TOTAL WATER RESOURCE	13,323.460 m ³ /day	27,759.610 m ³ /day
Upstream:	7,137.060 m ³ /day	8,107.710 m ³ /day
Downstream	6,186.400 m ³ /day	19,651.900 m ³ /day
TOTAL WATER BALANCE 2010	-27,760.585 m ³ /day	+1,007.140 m ³ /day
Upstream:	-25,442.585 m ³ /day	-2,165.239 m ³ /day
Downstream	-2,318.000 m ³ /day	+3,172.379 m ³ /day

SOURCE: Fieldwork by Shisanya and Luwesi (2012)

Water balance in Muooni resulted from a surplus of 3,172.38 m³/day enjoyed by downstream farmers and unmet water demands of 2,165.24 m³/day recorded by upstream farmers. In fact, the hydrological survey conducted in Muooni Catchment showed that more than 66 per cent of the total daily water demand (of 3,008.06 m³) for domestic and institutional use was abstracted by water projects operating therein. Schools, health centres and local industries were content with about 15.3 per cent, 5.8 per cent and 12.6 per cent, respectively. Daily water consumption by livestock was estimated to be 425.34 m³ upstream and 519.86 m³ downstream, with goats and cattle consuming about 70 per cent of the total demand. Finally, daily

water demand for irrigation averaged 26,752.47 m³, upstream and downstream farmers requiring 38.4 per cent and 60.6 per cent of the catchment's irrigation water, respectively, in the year 2010. In total, upstream farmers needed 10,272.95 m³/day while their downstream counterparts required 16,479.52 m³/day.

Concerning Ngusishi Catchment, a deficit of 25,442.59 m³/day was computed in the upper sub-catchment and unmet water demands of 2,318 m³/day were estimated for the lower zone, thus making a total deficit of 27,760.59 m³/day in 2010, in the whole catchment. Domestic and institutional water demands amounted to a total of 2,260.15 m³/day, Ngusishi Water Resource Users' Association (NWRUA) supplying 97.4 per cent to households (2,201.65 m³/day), while the remaining 2.6 per cent was allocated to health centres (1.4 per cent) and mini factories (1.2 per cent). Water demand for agriculture averaged 41,084.04 m³/day, upstream farmers abstracting about 79.3 per cent and their downstream counterparts being content with 20.7 per cent. Water demand by mini bakeries amounted to 1 m³/day while restaurants and hotels ordered about 25 m³/day, thus making a total of 26 m³/day. Finally, water demand for livestock in 2010 amounted to 29,252 m³ upstream and 35,752 m³ downstream.

If the simulation of the water balance sheet displayed a surplus in Muooni and a deficit in Ngusishi, in 2010, none of these catchments was expected to sustain a surplus in the long run. The best scenario for the future water balance for farmers therein would be the above normal rainfall regime (ANOR), one under which the catchment's balance sheet shows a surplus from 2011 up to 2017. In effect, under the ANOR scenario, the total water demand in 2011 in Ngusishi was valued at 13,394.926 m³/day, upstream farmers abstracting 10,675.756 m³ daily while downstream farmers were content with 2,719.170 m³/day. This water demand was predicted to peak at 41,648.238 m³/day in 2030, while the total resource available was projected to decrease from 37,073.14 m³/day (in 2011) to 12,810.18 m³/day (in 2030), thus leading to a deficit of 69.2 per cent of the predicted demand (which represents 225.1 per cent of the available resource in 2030). The upward rise in water demand was justified by irrigation expansion, mainly by upstream farmers, represents 96.8 per cent of the total water demand. Under a normal (NOR) and below normal (BNOR) scenario, very high unmet water demands are expected (Table 3).

Table 3. Future water balance in Ngusishi under BNOR scenario

Area	Resource	Demand	Balance	%Resource/ Demand	%Balance/ Demand	%Balance/ Recourse
2011						
Upstream	293.78	35,763.783	(35,470.00)	0.82	(99.18%)	(12,074
Downstream	456.36	9,109.22	(8,652.86)	5.01	(94.99%)	(1,896)
Catchment	750.14	44,873.002	(44,122.86)	1.67	(98.33%)	(5.882)
2030						
Upstream	280.67	111,198.714	(110,918.05)	0.25	(99.75%)	(39,519)
Downstream	436.00	28,322.88	(27,886.89)	1.54	(98.46%)	(6,396)
Catchment	716.66	139,521.598	(138,804.94)	0.51	(99.49%)	(19,368)

SOURCE: Fieldwork by Shisanya and Luwesi (2012).

Muooni Catchment will not escape from the fate of Ngusishi, even though its situation will be slightly better under a normal scenario. Nonetheless, if an Environmental Flow Reserve (EFR) of 30 per cent were to be enforced, both catchments would have experienced total water deficits starting by the year 2011 (Table 4).

Table 4. Projected growth and development in the selected catchments

Variables	Ngusishi		Muooni	
	2010	2011-2030		
Gross Domestic Product (GDP) per capita (US\$)	582.72	568.26	481.09	447.249
Population (Number of People)	5,049	6,055	20,425	28,582
Number of Households	1,685	2,021	4,639.30	6,491.98
Household Size (Nimber of People)	3.00	3.00	4.40	4.40
Average Income per household (US\$)	1,745.90	1,702.57	2,118.06	1,969.07
Annual PopulationGrowth Rate (%)	1.70	1.70	3.1	3.1
Income Growth Rate (%)	-0.24	-0.24	-0.7	-0.7
Cost of water supply (US\$/m ³)	0.0625	0.0629	1.849	1.870
Cost of water demand (US\$/m)	0.0828	0.0845	8.378	8.598
Development projectins (Level of Urbanization	10	6.5	6	3.873
Supply ternover under drought scenario Nov. 2009 ratio (US\$/m ³)	0.063	0.063	0.050	0.050
Cost of water supply under drought scenario (US\$/m ³)	1.00	1.0064	12.424	12.57
Cost of water demand under drought scenario (US\$/m ³)	1.3244	1.3514	56.30	57.783
Supply ternover under flood scenario (Dec. 1981 ratio	3.350	3.350	1.826	1.826
Cst of water supply under flood scenario (US\$/m ³)	0.0187	0.0188	1.012	1.024
Cost of water demand under flood scenario (US\$/m ³)	0.0247	0.0252	4.587	4.708

SOURCE: Fieldwork by Shisanya and Luwesi 2012

Note: ¹ Annual average

Based on the above predictions, conflicts on appropriation of water resources are likely to arise very early in both catchments, even under normal weather conditions. Worse water stresses will be experienced by farmers under a drought scenario, if no appropriate political and institutional response is accorded to mitigate these risks, among which a wide-scale implementation of GWS schemes in the two catchments is necessary (Gleditsch et al. 2004).

3.2.4 Farmers' Vulnerability to Drought

The decreasing trend of water resources vis-à-vis increasing patterns of water abstractions indicate that farmers living in the ASALs of Kenya are highly vulnerable to drought. Fig. 2 shows that farmers' vulnerability to drought was estimated at 53.3 per cent in Ngusishi (against 4.3 per cent vulnerability to flood), and 97.4 per cent in Muooni (compared to 2.7 per cent vulnerability to flood). This was mostly due to the collapse of the available ecosystem in Ngusishi Catchment under severe drought (94 per cent), while a fair sociopolitical impact (54 per cent) and a minor economic impact (21.9 per cent) were recorded in this catchment. Likewise, the biophysical, sociopolitical and economic impacts of drought in Muooni Catchment were rated as "severe" (95 per cent), "major" (85 per cent) and "fair" (51.2 per cent), respectively. This issue of drought is perpetual in the ASALs but good management is the key towards ensuring resource optimization and sparing communities from becoming vulnerable to water disasters.

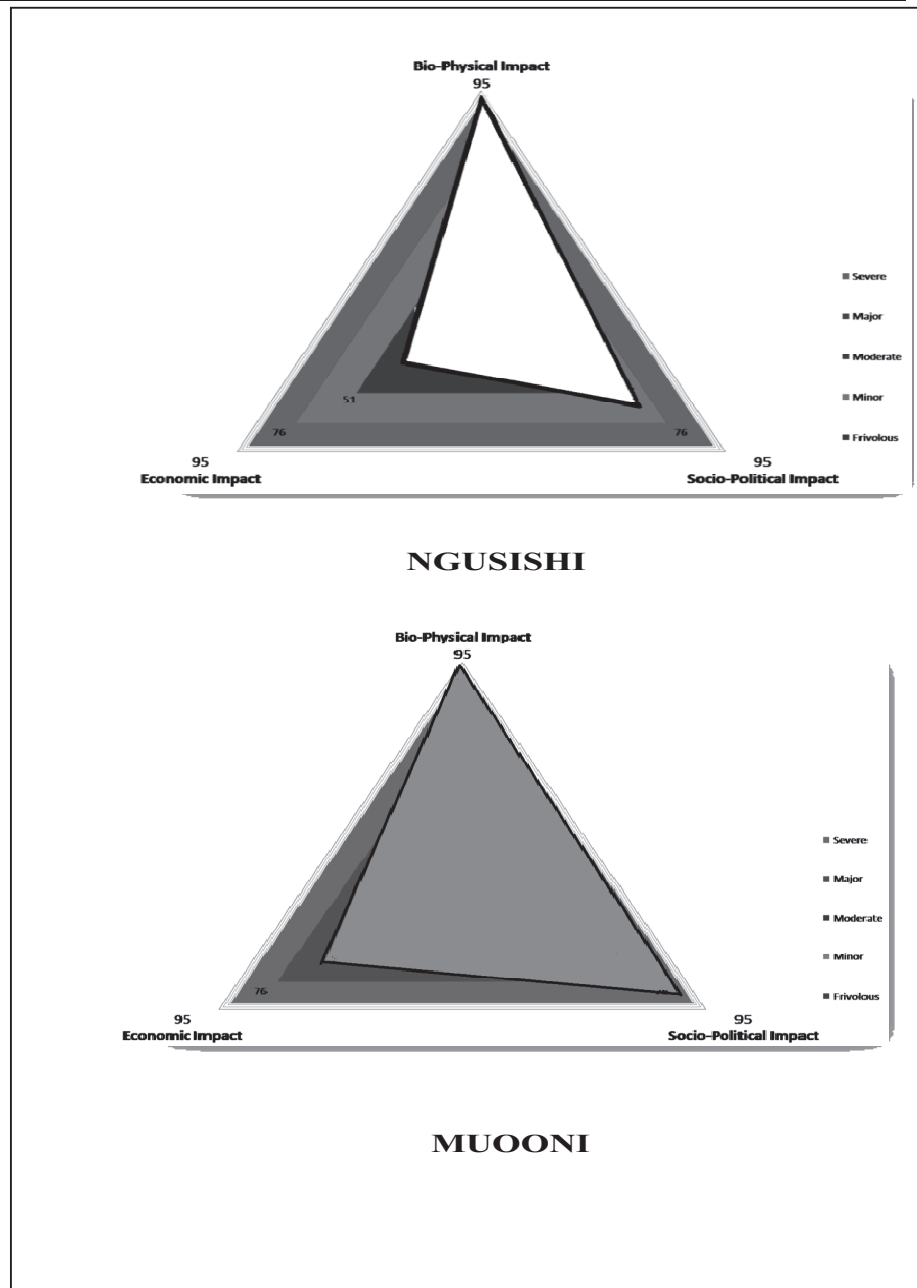


Figure 2: Farmers' Vulnerability to Drought in Selected Catchments of Kenya ¹

Note: ¹ The shadowed triangle in the centre of the figure shows vulnerability to drought

Source: Fieldwork by Shisanya and Luwesi 2012

Cosgrove and Rijsberman (2000) rightly put it in their book “World Water Vision: Making Water Everybody’s Business”, when they declare: “There is a water crisis today. But the crisis is not about having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people — and the environment — suffer badly.” Clarke and King (2004) also echo this statement by saying: “With few exceptions (Bahrain is one), aridity is only one aspect of a situation in which water availability combines with other factors — including ease of access to water, the efficiency with which resources are used, the capacity of people to benefit and the health of the environment — to determine what is known as “WATER POVERTY.” These findings confirm that GWS schemes are biophysically needed to satisfy water demands of both upstream and downstream farmers in the Kenyan ASALs. Though unrecognized and unrewarded by many water managers, their implementation is possible but its feasibility would likely depend on the institutional performance or sociopolitical acceptability of the schemes. The following three sub-sections provide details on the sociopolitical acceptability of GWS schemes in Muooni and Ngusishi catchments.

3.3 Innovative Farming Water Saving Strategies to Curb Drought Effects

Local stakeholders in Muooni were lauded for their strict adherence to SWC measures, as shown by the re-greening of their catchment area (Figure 1). Though Ngusishi Catchment was browning, farmers have performed well in building a strong institution for managing water resources therein, namely the Ngusishi Water Resource Users’ Association (NWRUA). This institution is not only coordinating water supply and demand but also fostering the implementation of GWS schemes in the catchment. About 46.2 per cent of farmers living upstream in Ngusishi Catchment and 20.6 per cent of downstream farmers revealed having been involved in a GWS scheme. Figure 3 reveals different types of Payments for Watershed Services (PWS) offered by downstream farmers and accepted by their upstream counterparts. Despite the fact that they are not directly bound by a PWS agreement to each other, Muooni farmers likewise demonstrated both their Intention to Pay (ITP) and Intention to Accept compensation (ITA) for a GWS scheme. In effect, 25 per cent of farmers living upstream and 22.8 per cent among their downstream fellow workers had already heard about a specific type of GWS scheme. These farmers wished to implement Green Water Credits and seven other major schemes (Figure 3). Nevertheless, Muooni farmers needed strong institutional frameworks for managing the whole catchment and increasing their capability to implement GWS schemes, if disastrous drought effects are expected to be curbed in their catchment.

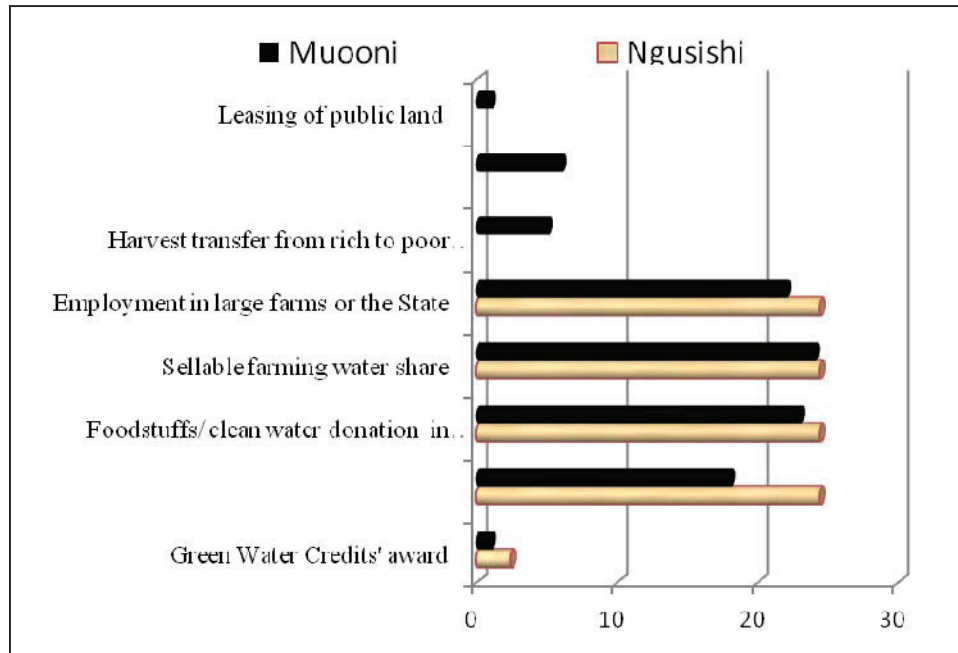


Figure 3: Types of Green Water Saving Schemes Reported by Farmers in Selected Catchments of Kenya

Source: Fieldwork by Shisanya and Luwesi, 2012

Farmers in the selected catchments of the Kenyan ASALs are using both hard and soft green water saving technologies to develop and conserve their water resources. Hard green water saving technologies range from SWC measures to efficient irrigation schemes and rainwater harvesting. A clear example of these hard technologies was given by the implementation of drip irrigation by Amiran Agro-Business Centre in Ngusishi and the entire Meru County, to minimize water loss from sprinklers, furrows and wetland diversion by at least 30 per cent (Figure 4).

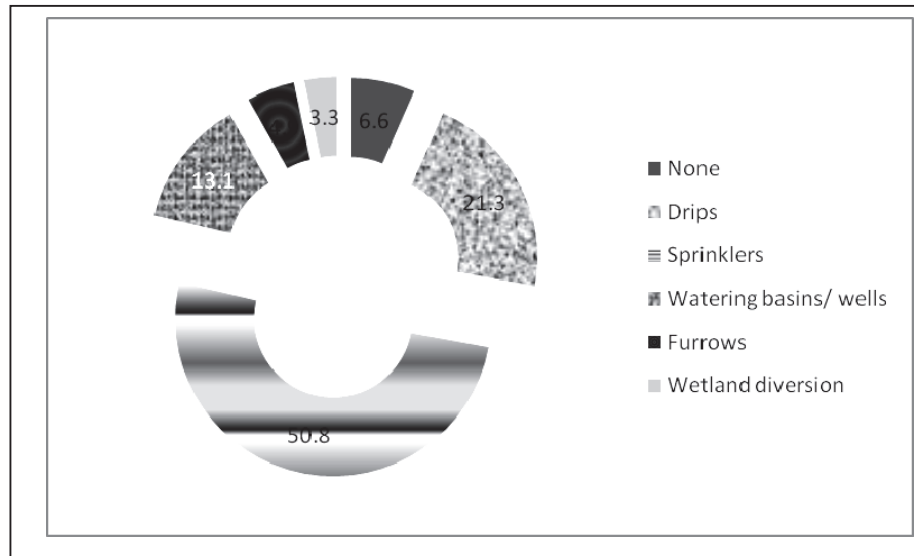


Figure 4: Plant Water Saving Techniques used in Ngusishi

Source: Fieldwork by Shisanya and Luwesi, 2012

An illustration of soft green water saving technology was found in Musingini Village, which neighbours the upper Muooni sub-catchment. It features an automated borehole project powered by solar panels and activated by M-Pesa mobile phone technology (Figure 5). This project was initiated by Grundfos Lifelink (Denmark) and the mobile operator Safaricom (Kenya). These results demonstrate that GWS schemes are not only biophysically needed but also possible to implement and socially acceptable to farmers living in the ASALs. Yet, performing institutions are needed to spearhead their full implementation.

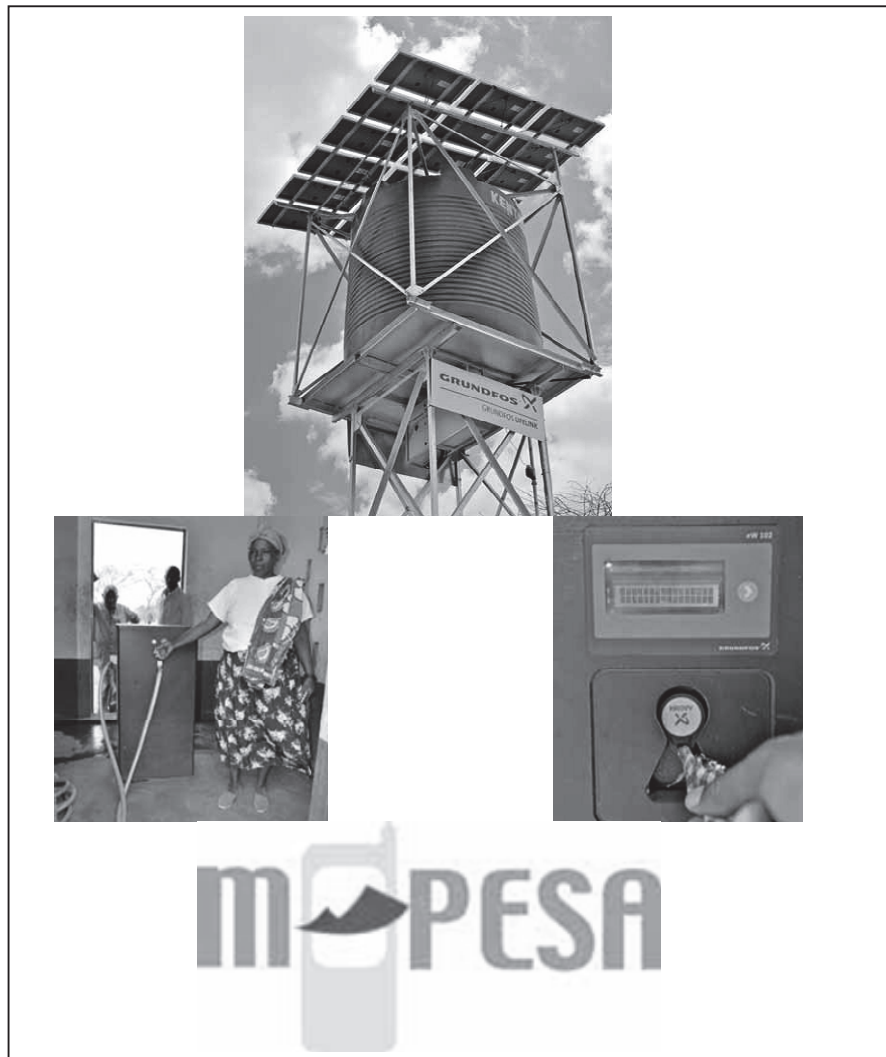


Figure 5: Automated Water Pump Activated by Mobile Phone in Musingini

Sources: Photos compiled from Karago, 2009

3.4 Performance Rating of Water Institutions for Saving Green Water

Performance-based Management Rating (PMR) was used to appraise water institutions' effectiveness with regard to: (i) Contribution to environment sustainability; (ii) Business success; (iii) Contribution to economic development; (iv); Contribution to social peace and welfare; (v) Own institutional sustainability (Adrianto and Yoshiaki 2002). Water institutions operating in Ngusishi obtained a performance rate of 76 per cent (meaning "good") with regard to the implementation of GWS schemes, while the effectiveness of Muooni institutions was "fairly good" (54.4 per cent) (Figure 6). Water institutions operating in Ngusishi Catchment were found to be effectively "good" in addressing challenges related to high storm intensity and flash flooding (61.6 per cent capability index vis-à-vis 4.3 per cent vulnerability index). However, they were said to be "fairly poor" in curbing warming effects resulting from minimum temperature increase (29 per cent capability index against 22.4 per cent vulnerability index).

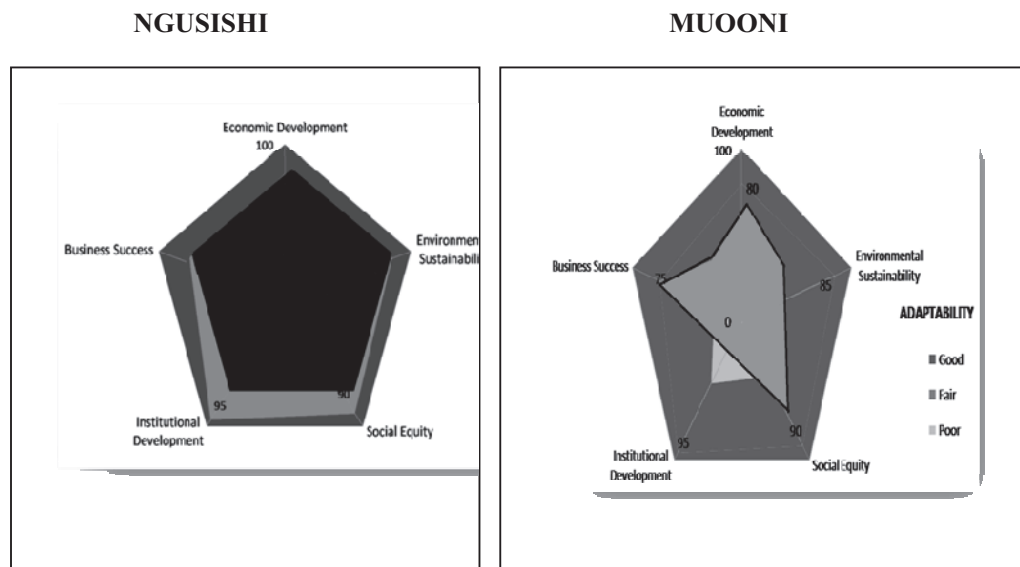


Figure 6: Farmers' Capability to Curb Drought in the Selected Catchments of Kenya

Note: ¹ The shadowed polygon in the centre of the figure shows capability to curb drought.

Source: Shisanya and Luwesi 2012

Ngusishi water institutions performed “poorly” in addressing drought effects arising from decreasing river discharge and soil moisture in the catchment (24.2 per cent capability index versus 53.3 per cent vulnerability index). Similarly, water institutions’ capability in Muooni Catchment ranged from “poor” to “good”. Their performance was rated “good” with regard to controlling storm intensity (78.4 per cent capability index vis-à-vis 2.7 per cent vulnerability index) but “poor” owing to the decreasing effect of drought on river discharge and soil moisture in the catchment (2.2 per cent capability index against 97.4 per cent vulnerability index), to the warming effect of increased minimum temperatures (2.7 per cent capability index versus 72.4 per cent vulnerability index).

Hence, the performance of GWS schemes in both drought stricken catchment areas was not totally felt on the ground. This was due to limited natural, social and economic resources vis-à-vis the high intensity of drought hazards, which are often exacerbated by El Niño and La Niña cycles in both catchments. In such a context, increased social networking may increase farmers’ ability to initiate Public Private Partnerships (PPPs), to compensate for the collapse of biophysical and economic systems in their catchments (Miller et al.1997; Adger 2000; Pelling 2004). Disaster preparedness and management shall also improve institutional capability by ensuring that water is availed equitably to all in normal times as well as under stressful conditions (Berg 2007; Agrawal and Perrin 2008). This will enable a smooth running of GWS schemes in the catchment, particularly in Muooni. If these schemes become environmentally possible and socially friendly, farmers’ vulnerability to water disasters may be alleviated in most ASALs of Kenya. So, what hinders their full uptake by policy-makers and catchment managers? The following economic feasibility study will yield more information.

3.5 Economic Efficiency and Financial Sustainability of GWS Schemes

Blue Water Supply (BWS) projects operating in Muooni performed well under conditions of drought rather than flooding. In contrast, GWS schemes were specifically found to be inefficient and economically unprofitable when targeting agricultural production under conditions of drought. Nonetheless, they recorded high efficiency rates and BCRs under a flooding scenario (ANOR). The following sub-sections present the economic efficiency and cost recovery of GWS schemes, and farmers’ affordability and GWS schemes’ financial sustainability in the catchment.

3.5.1 Economic Efficiency and Cost Recovery of GWS Schemes

GWS schemes surveyed in the ASALs of Kenya had a very high level of efficiency under ANOR, even though their total cost, technical and allocative efficiencies were in most cases insignificant, especially under drought conditions. This was explained by the fact that crop water requirements were much higher than what farmers could afford, in terms of

farming water demand (Table 5). An economic valuation of the marginal farming water demand indicated that 81.5 per cent of Ngusishi farmers could afford a monthly volume of 7.9 m^3 (with a standard deviation of 26.5 m^3) while only 68.7 per cent of farmers in Muooni Catchment could afford as high a monthly volume as 27.6 m^3 (with a standard deviation of 47.7 m^3). Earning marginal revenues of US\$ 4.4 and US\$ 6.36 per month in Ngusishi and Muooni, respectively, these farmers' water profitability and solvability were still lacking in substance. Henceforth, farmers had a tendency to use inefficient cropping methods and water management techniques that significantly undermined their total economic efficiency, and increased their farming water losses.

Table 5. Farmers' water demand and crop requirements in the study areas in 2010

Catchment	1 Annual farmer water demand (m^3)	2 Annual crop water requirement (m^3)	(3)=(2)-(1) Gap (m^3)	(4)=100*(3)/(2) Percentage gap (%)
Ngusishi	2,544.45	38,758.89	36,214.44	93.44%
Muooni	709.35	23,404.14	22,694.79	96.97%

SOURCE: Fieldwork by Shisanya and Luwesi (2012).

Ngusishi Catchment presented a case of subsidized blue water supply while Muooni appeared to be a haven for greedy water vendors. This subsidization of water prices by the NWRUA in Ngusishi Catchment was impacting negatively on water vendors' revenues, thus leading to a decrease of farming water cost at annual rates of 4 per cent. BWS projects were expected to incur losses under the ANOR scenario (flooding), the price of a cubic meter predicted to stabilize around US\$ 0.01, while GWS schemes would enjoy a high BCR of 15.9, arising from benefits recorded by farmers under ANOR. A similar situation was projected in Muooni Catchment, despite the fact that there was no catchment management authority that could stabilize the price of blue water. However, GWS schemes would likely record a high BCR of 5.1 under flooding conditions, possibly due to the high water productivity (of US\$ $7/\text{m}^3$) originating from the schemes' technological efficiency (Figure 7). Table 6 however reveals that no cost efficiency will be recorded under any rainfall regime by GWS schemes. This is likely due to their limited technical and allocative efficiencies under the NOR and ANOR scenario for Muooni, and the NOR for Ngusishi, despite their high potential scale efficiency under any scenario. GWS schemes will thus need to increase their technical and allocative efficiencies to save more water during the ANOR, to supplement water deficits projected under the NOR (normal) and BNOR (drought) scenarios at a fair price.

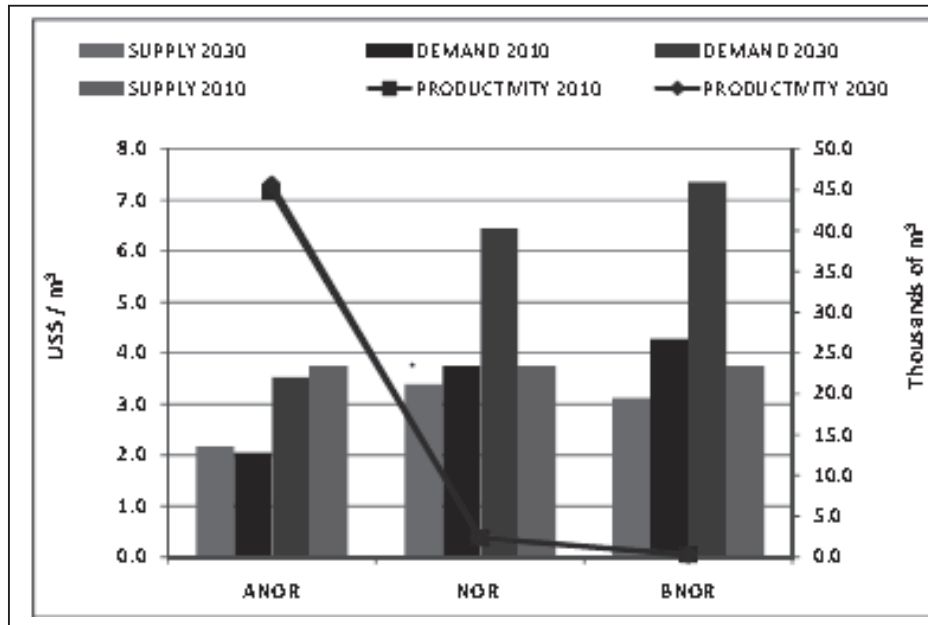


Figure 7: GWS Schemes' Productivity under Flooding Conditions in Muooni

Source: Fieldwork by Shisanya and Luwesi, 2012

Table 6. GWS Schemes' economic efficiency in Ngusishi and Muooni by the year 2030

NGUSISHI						
Scenario	Qty (M³)	Water Productivity	Total cost Efficiency	Technical Efficiency	Allocative Efficiency	BCR
ANOR	260.17	4.64	0.002	0.273	0.007	15.92
NOR	666.74	3.77	0.019	1.232	0.015	-0.06
BNOR	830.14	3.28	0.268	0.001	0.268	-0.974
MUOONI						
ANOR	12,702.7	6.98	0.049	2.773	0.018	5.09
NOR	5,202.31	78.93	0.213	0.132	1.613	-0.42
BNOR	7,942.08	68.06	0.453	0.010	0.453	-0.997

SOURCE: Fieldwork by Shisanya and Luwesi (2012)

Compared to GWS schemes, BWS projects are only economically viable under normal and below normal climatic conditions prevailing in the ASALs of Kenya. Farmers operating in Ngusishi Catchment will be facing enormous daily unmet demands of 12,425 m³ in 2030 under the ANOR scenario, with decreasing annual growth rates of -4.2 per cent in the supply and increasing demands of +4.5 per cent, but the price of water would be stabilized at US\$ 0.07/m³. Under the NOR scenario, unmet demands of about 86,000 m³/day are expected in 2030, with average prices of US\$ 0.08 /m³ (in 2030). This situation will worsen under the BNOR scenario when the unmet demands will rise to 98,234 m³/day in the year 2030. Surprisingly, blue water businesses are not expecting any economic profitability, neither under the NOR scenario (BCR= 0.17) nor under the BNOR (BCR= -0.70) nor under the ANOR scenario (BCR= - 0.1). Under such conditions, the subsidization policy is to be banished by catchment management authorities, if significant benefits are to be projected for BWS projects.

However, BWS projects were found to be economically rentable than GWS schemes in a water scarce area such as Muooni, under normal conditions (NOR) and during drought (BNOR). These projects recorded BCRs of 3.72 and 2.38 under NOR and BNOR, respectively, but lacked economic viability under conditions of flooding (ANOR), with a BCR of 0.23. In effect, BWS projects operating in Muooni Catchment are expecting high cost efficiency rates of 1.52 and 1.00, respectively, under drought (BNOR) and normal (NOR) conditions, with a water productivity averaging US\$ 50 /m³. Decreasing water supply under ANOR scenario (of 60,000 m³/day in 2010) will nearly settle at 2,000 m³/day in 2030, under the BNOR scenario, while farmers' daily water demand will be set around 27,000 m³/day under any scenario. Besides, the absence of an authority regulating water prices will boost BWS projects' profitability in Muooni Catchment along with their high technical efficiencies of 2.77 and 1.00, recorded under the NOR and BNOR scenarios, respectively, in the year 2030. Though burdensome for farmers, these water businesses will be charging at least US\$ 10 /m³ under overflow (ANOR) and up to an average of US\$ 52 /m³ under normal and drought conditions (Figure 8). They are expected to make as gross profits as high as US\$ 2,191.73 /day in 2030 under the ANOR scenario, with demand increasing faster than supply by 2.75 per cent in the year 2035. These water vendors will be more profitable under NOR and BNOR scenarios, their record of profitability ranging from 23 per cent (in 2010) to 161 per cent (in 2030) under the BNOR scenario.

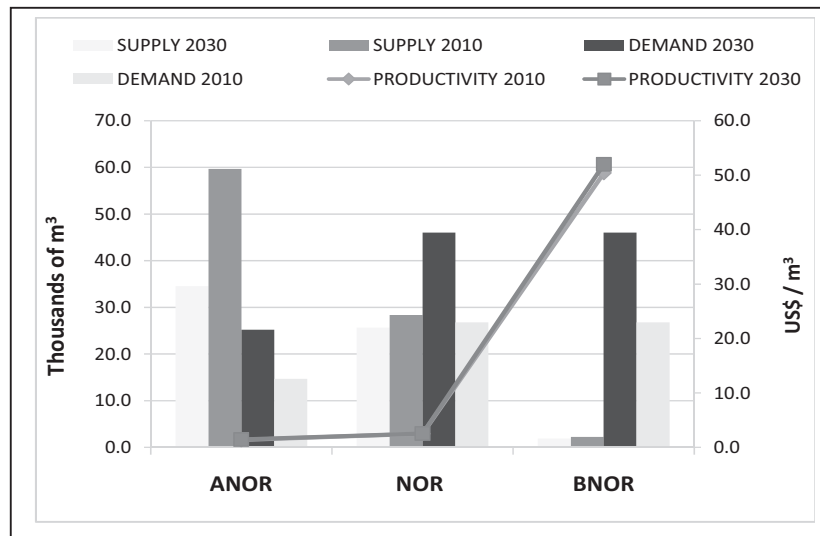


Figure 8: BWS Projects' Productivity in Muooni by 2030

Source: Shisanya and Luwesi, 2012

The kind of economic mania and greed displayed by water vendors venturing in Muooni Catchment was deplored by Kindelberger and Aliber (2005) as the main cause of panic and unsustainable marketing, leading to financial crises in the long run. This situation is mainly attributed to lack of adequate policies and regulations in the absence of an institution coordinating catchment management. Therefore, GWS schemes will be very instrumental in fostering water sustainability and productivity under conditions of flood and drought, to enable farmers' achieve farming water allocative efficiency and economic optimum in Muooni. The latter was estimated to an "Economic Order Quantity" (EOQ) of 12,702.7 m³/day under a flooding scenario, or a "Limit Average Cost" (LAC) of 5,202.31 m³/day under normal scenario, or a "Minimum Efficient Scale" (MES) of 7,942.08 m³/ day under a drought scenario.

3.5.2 Farmers' Affordability and GWS Services' Financial Sustainability

Finally, a contingent valuation of downstream farmers' "Willingness to Pay" (WTP) for GWS services and their upstream counterparts' "Willingness to Accept compensation" (WTA) was conducted to confirm or refute the financial sustainability of GWS schemes. A WTA of US\$ 108.33/ month was computed for each of the 1,011 households located in upstream Ngusishi, against a WTP of US\$ 11.61 multiplied by 674 households located downstream. The analysis concluded that the implementation of GWS schemes in Ngusishi would result in a monthly

deficit of US\$ 101,696.49. Likewise, GWS schemes in Muooni Catchment will incur a monthly deficit of US\$ 485,816.22, with downstream farmers expressing a WTP of US\$ 21.82 monthly (multiplied by 2,549 households), against a WTA of US\$ 259.06 per month (multiplied by 2,090 households) by upstream farmers. GWS schemes operating in Muooni and Ngusishi would thus need to ensure their cost recovery by raising substantial funds from other agencies, thus impeding their financial self sufficiency and economic feasibility in the long run. Little wonder that many catchment managers remain skeptical about the ability of these schemes to ensure cost recovery. A merger between an authoritative GWS scheme and a cost-effective BWS project may help minimizing deficits in water productivity and ensure higher BCRs under conditions of drought (Luwesi et al. 2012). These findings are expected to drive reforms for enhancing investment in agricultural water development in Kenyan ASALs, following the recommendations provided in the next section..

4. Conclusion

This study was based on four major assumptions, notably: (i) GWS schemes are biophysically required in most ASALs of Kenya because farmers living here are mostly vulnerable to drought; (ii) Farmers in the ASALs significantly rely on ineffective traditional Soil and Water Conservation (SWC) measures to mitigate the effects of drought rather than implement modern technologies, including conventional GWS schemes; (iii) Unsound management of the catchment's land and water resources triggers vulnerability to drought and ineffectiveness of GWS schemes; (iv) Specific GWS schemes used by farmers are insignificantly cost-efficient and profitable in agriculture, specifically under conditions of drought, compared to blue water saving projects. Below are results and recommendations after testing the hypotheses.

4.1 Farmers' Vulnerability to Drought

No doubt, farmers living in Kenyan ASALs are more vulnerable to drought than floods. This study accepted the first hypothesis upholding the biophysical need of GWS schemes to curb farmers' vulnerability. It revealed that the two selected catchments displayed a high rate of dependence on surface water resources, hence leading to high vulnerability to drought. The predicted blue water balances for 2010-2030, revealed high rates of unmet water demands over the years, owing to drought intensity and high water abstraction from the upper sub-catchment of Ngusishi and downstream Muooni. The latter were likely attributed to the pressure of population expansion and land use changes on natural ecosystems, which were triggered by the collapse of sociopolitical systems that are supposed to guide water allocation and natural resource development in the catchment area. Under such conditions, enhanced social networking may increase farmers' economic assets to compensate for the collapse of their catchment's biophysical and sociopolitical systems. However, in the

absence of a coordinating authority, high water prices, even under normal periods, are likely to be burdensome to farmers but profitable to water vendors, particularly in Muooni Catchment. GWS schemes are, therefore, environmentally crucial and socially accepted by both upstream and downstream farmers, to enhance sustainability towards the management of water resources. Moreover, farmers being unable to meet the natural water requirements of their plants, specifically under drought, necessitates that GWS schemes will have to allocate crop Evapo-Transpiration Quotas (ETQs) to farmers. This will enable them to efficiently utilize their little water endowment through employment of rational crop selection and specialization of two or three crops, as indicated in the Kenyan Vision 2030. Improved crops, such as Marama beans, buffalo gourds and sorghum or millet, would thus reduce excessive opportunity costs and other external costs related to the shortage of water. Still, the Government of Kenya will need to introduce a robust programme in response to hydro-climatic risks, to boost a green water economy as a means for preparedness to water disasters.

4.2 Farmers' Capability to Curb Drought Using Innovative Technologies

The second hypothesis insinuating the impossibility for conventional GWS schemes to be implemented by farmers living in the ASALs was significantly rejected. In effect, farmers' reliance on ineffective traditional SWC measures did not hinder their innovativeness and use of modern technologies, including conventional GWS schemes, to mitigate the effects of drought. This was clearly evidenced by the numerous water-saving technologies investigated in Muooni and Ngusishi catchments, ranging from traditional Soil and Water Conservation (SWC) measures to modern hydro-policies, and from hard to soft agro-technologies. But in most of the cases, farmers have remained traditionally minded and need to be prepared to adapt to technological change by both local and external development partners such as Grundfos Lifelink and Safaricom M-Pesa (for the automated pump in Muooni), or Amiran Agro-business Centre (for drip irrigation in Ngusishi). Besides, the effectiveness of traditional SWC technologies is not significantly felt by farmers, owing to recurrent water shortages and intensive hydro-climatic changes that lead to the collapse of BWS projects and increase farming water costs over the years, thus significantly undermining farming water productivity. Consequently, it would be appropriate for water resource management institutions to implement contingency plans and build farmers' capacity to upgrade existing GWS schemes, to measure up to hydro-climatic risks attributed to climate change and other environmental risks derived from water unfriendly land use activities, such as eucalyptus tree planting, in the catchment area. Hence, a linkage between efficient BWS projects and soft green water technologies should be encouraged to provide clean, safe and solvable water services to farming communities lacking access to surface water resources. The Ministry of Environment, Water and Natural

Resources should work towards disseminating such innovative and efficient technologies, across the country, hence supply piped water to schools, dispensaries, market places, and places of worship, to achieve universal access to portable water, in line with Millennium Development Goal (MDG) 7 and the Sustainable Development Goals (SDGs).

4.3 Capability of Catchment Management Institutions to Implement GWS Schemes

Yet, the lack of sufficient institutional capability and weak agricultural productivity heightened farmers' vulnerability to drought and drought-flood cycles. If no precautionary measures are taken, the implementation of GWS schemes is unlikely to be feasible. This partly confirmed the third hypothesis of the study, namely unsound management of the catchment's land and water resources triggers vulnerability to drought and ineffectiveness of GWS schemes, especially in the case of Muoni Catchment. However, the capability of water management institutions is fairly adequate in Ngusishi Catchment, for implementing GWS schemes. What they require is additional capacity-building to enhance the technological efficiency and effectiveness of their GWS schemes. In this regard, the Water Resources Management Authority (WRMA) needs to expedite the creation of Water Resource Users' Associations (WRUAs) across the country. It should also design a capacity-building programme to improve the capability of catchment management institutions to manage the catchment and enhance efficiency of their water allocation plans. The WRMA and WRUAs may also require contingency plans for upgrading existing GWS schemes to adapt to technological advancements and measure up to hydro-climatic trends projected for each catchment area.

4.4 Green Water Use Cost-Efficiency and Profitability in Agriculture

Compared to BWS projects, GWS schemes' lack of economic efficiency and their inability to ensure cost recovery in times of drought was very obvious. This made it difficult for farmers' to compensate the huge gap between their downstream fellow workers' Willingness to Pay (WTP) and their upstream counterparts' Willingness to Accept compensation (WTA) for their green water services. It could also fail to incentivize catchment managers to recognize and reward GWS schemes. Consequently, the fourth hypothesis of this study was fully accepted. The following guidelines would drive reforms toward enhancing investment in agricultural water development in the Kenyan ASALs.

Farmers need innovative farming technologies to increase water productivity and water use efficiency in agriculture. This ranges from crop selection to the acquisition of water storage facilities such as tanks and dams, via automated technologies. Grundfos Lifelink's pumps connected to Amiran drips may supplement water substantially to farmers. Hence, GWS schemes could save water under flooding conditions (ANOR), especially downstream, to meet increased crop water requirements under normal

(NOR) and below normal (BNOR) weather conditions. They would also need to design water allocation plans to allot available water resources. Farmers could then supplement their water deficits with excess rainwater stored under the ANOR regime to maintain their actual crop water requirements under the BNOR rainfall. Moreover, a fair pricing policy is required to boost farming water profitability within the economic production possibility frontiers, namely the Economic Order Quantity (EOQ) under a flooding scenario, the Limit Average Cost (LAC) under a normal scenario, and the Minimum Efficient Scale (MES) under a drought scenario. That is how GWS schemes would improve both the Benefit-Cost Ratio (BCR) of farming water and its efficient use under fluctuating rainfall regimes. This new farming water policy should be perceived in terms of mechanisms that link agricultural decision-making to agricultural production and marketing, namely prices, regulatory and participatory mechanisms, and related processes in other sectors, including water resources allocation, pricing and management, land use and other natural resources management, as well as disaster planning and preparedness. All these mechanisms will enable GWS schemes to be not only innovative, needed and accepted by farmers, but also financially sustainable and economically feasible.

References

- Adger, W. N. 2000. Institutional adaptation to environmental risk under the transition in Vietnam. *Annals of the Association of American Geographers*, 90 (4): 738-758.
- Adrianto, L. and Yoshiaki, M. 2002. Developing economic vulnerability indices of environmental disasters in small island regions. *Environmental Impact Assessment Review*, 22: 393-414.
- Agrawal, A. and Perrin, N. 2008. Climate adaptation, local institutions and rural livelihoods. International Forestry Resources and Institutions (IFRI). Working Paper 081-6. Michigan: School of Natural Resources and Environment, University of Michigan.
- Al-Salaymeh, A., Al-Khatib, I. and Arafat, H. 2011. Towards sustainable water quality: management of rainwater harvesting cisterns in Southern Palestine. *Water Resources Management*, 25: 1721-1736.
- Anandajayasekeram, P., van Rooyen, C. J. and Liebenberg, F. 2004. *Agricultural projects planning and analysis: A source book*. A joint publication by University of Pretoria, FARMESA and University of Ghent. Gent, Belgium.
- Barah, B. C. 2009. Economic and ecological benefits of system of rice intensification (SRI) in Tamil Nadu. *Agricultural Economics Research Review*, 22: 209-214.
- Bates, B. C., Kundzewicz, Z. W., Wu, S. and Palutikof, J. B. 2008. Climate change and water. A technical paper of the Intergovernmental Panel on

- Climate Change (IPCC). Geneva: The IPCC Working Group II Technical Support Unit, IPCC Secretariat.
- Berg, S. V. 2007. Conflict resolution: benchmarking water utility performance. *Public Administration and Development*, 27 (1): 1–11.
- Berntell, A. 2008. Getting to business not as usual. *Stockholm Water Front*, 1: 1-2.
- Brown, L. R. 2001. *Eco-economy: Building an economy for the Earth*. NY: Norton and Company Ltd.
- Cheserek, G. 2005. Indigenous knowledge in water and watershed management: “Marakwet” conservation strategies and techniques. *FWU Water Resource Publications*, 3: 25-33.
- Clarke, R. and King, J. 2004. *The atlas of water*. London: Earthscan Publications Ltd.
- Cosgrove, W. J. and Rijsberman, F. R. 2000. *World water vision: Making water everybody's business*. London: Earthscan Publications Ltd.
- Dent, D. and Kauffman, S. 2007. The spark has jumped the gap: Green Water Credits proof-of-concept. In *Green Water Credits Report 7*, edited by D. Dent. Wageningen: ISRIC-World Soil Information.
- Department for Transport (DfT). 2011. Cost Benefit Analysis. TAG Unit 3.5.4. London: Department for Transport. Retrieved June 25, 2012, from www.dft.gov.uk/webtag.
- Downing, T. E. 2003. Linking sustainable livelihoods and global climate change in vulnerable food systems. *Die Erde*, 133: 363-378.
- Falkenmark, M. and Rockström, J. 2004. *Balancing water for humans and nature*. London: Earthscan Publications Ltd.
- Förch, G., Winnege, R. and Thiemann, S. 2005. DAAD alumni summer school 2005: Topics of integrated water resources management. *Weiterbildung in Siegen*, 18: 1-180.
- Geertsma, R., Wilschut, L. and Kauffman, S. 2010. Review for the Green Water Credits pilot operation in Kenya. In *Green Water Credits Report 8*, edited by S. Kauffman. Wageningen: ISRIC-World Soil Information.
- Gleditsch, N. P., Owen, T., Furlong, K., and Lacina, B. 2004. Conflicts over shared rivers: Resource wars or fuzzy boundaries? The 4th Annual Convention of the International Water Studies Association, Montreal, March 2004.
- Grieg-Gran, M., Noel, S. and Porras, I. 2006. Lessons from payments for environmental services. In *Green Water Credits Report 2*, edited by D. Dent. Wageningen: ISRIC-World Soil Information.

- Hessel, R., Messing, I., Liding, C., Ritsema, C. and Stolte, J. 2003. Soil erosion simulations of land use scenarios for a small Loess Plateau catchment. *Catena*, 54 (1–2): 289–302.
- Hoff, H., Stacey, N. and Droogers, P. 2007. Water use and demand in the Tana Basin: Analysis using water evaluation and planning tools (WEAP). In *Green Water Credits Report 4*, edited by D. Dent. Wageningen: ISRIC-World Soil Information.
- Hoff, H., Falkenmark, M., Gerten, D., Gordon, L., Karlberg, L., and Rockström, J. 2010. Greening the global water system. *Journal of Hydrology*, 384: 177–186.
- Huggins C. 2002. Water policy and law in a water-scarce country. In *The changing face of irrigation in Kenya*, edited by Murray-Rust and Blank. Colombo: International Water Management Institute (IWMI).
- Hulme, M., Doherty, R., Ngara, T., New, M., and Lister, D. 2001. African climate change: 1900 – 2100. *Climate Research*, 17: 145–168.
- Hunink, J. E., Immerzeel, W. W., Droogers, P. and Kaufmann, S. 2010. Green Water Credits for the Upper Tana Basin, Kenya. Phase II - Pilot Operations: Biophysical assessment using SWAT. *Green Water Credits Report 10*. Wageningen: ISRIC-World Soil Information.
- Immerzeel, W. W., van Beek, L. P. H. and Bierkens, M. F. P. 2010. Climate change will affect the Asian water towers. *Science*, 328, June 11, 2010 issue. Retrieved November 18, 2011, from www.sciencemag.org.
- Islam, M., Chou, F., Kabir, M., and Liaw, C. 2010. Rainwater: A potential alternative source for scarce safe drinking and arsenic contaminated water in Bangladesh. *Water Resources Management*, 24: 3987–4008.
- Jaetzold, R., Schmidt, H., Hornetz, B. and Shisanya, C. 2007. Farm management handbooks of Kenya: *Natural Conditions and Farm Management Information*, 2, Part C, Subpart C1. Nairobi: Ministry of Agriculture and GTZ.
- Jones, R. G., Noguer, M., Hassell, D. C., Hudson, D., Wilson, S. S., Jenkins, G. J. and Mitchell, J. F. B. (2004). Generating high resolution climate change scenarios using PRECIS. Exeter: Met. Office Hadley Centre.
- Karago, C. 2009. A lifeline of water. *The Option*, Dec. 2009-Feb. 2010, pp.12-15.
- Kasambala, S., Kamara, A. B. and Nyange, D. 2006. Water resources and food security: Simulations for policy dialogue in Tanzania. In *Water governance for sustainable development*, edited by S. Perret, S. Farolfi and R. Hassan. London: Earthscan Publications Ltd, pp. 189-204.
- Kauffman, S., Droogers, P., Odada, E., Macharia, P., Gicheru, P., and Dijkshoorn, J. A. 2007. Green and Blue Water Resources and assessment of soil and water management scenarios using an integrated modelling framework. In

- Green Water Credits Report 3*, edited by D. Dent. Wageningen: ISRIC-World Soil Information.
- Kazbekov, J., Abdullaev, I., Manthrilake, H., Qureshi, A. and Jumaboev, K. 2009. Evaluating planning and delivery performance of water user associations (WUA) in Osh Province, Kyrgyzstan. *Agricultural Water Management*, 96: 1259-1267.
- Kindelberger, C. P. and Aliber, R. 2005. Manias, panics and crashes - A history of the financial crises. 5th edition. NJ: John Wiley & Sons, Inc.
- Kitissou, M. 2004. Hydropolitics and geopolitics: Transforming conflict and reshaping cooperation in Africa. *Africa Notes*, issue of November-December 2004.
- KNBS. 2007. Kenya Vision 2030. Retrieved July 3, 2009, from http://www.investmentkenya.com/Documents/Publications/vision_2030_BR_OCHURE_July_2007.pdf.
- KNBS. 2010. *Kenya 2009 population and housing census*. Nairobi: Government Printers.
- Ledec, G. and Quintero, J. D. 2003. Good dams and bad dams: Environmental criteria for site selection of hydroelectric projects. In *Latin America and Caribbean region environmentally and socially sustainable development, working paper 16*. Washington D.C: The World Bank.
- Legesse, D., Vallet-Coulomb, C., and Gasse, F. 2003. Hydrological response of a catchment to climate and land use changes in Tropical Africa: Case study South-Central Ethiopia. *Journal of Hydrology*, 275 (1–2): 67–85.
- López-Baldovín, M. J., Gutiérrez-Martín, C. and Berbel, J. 2006. Multicriteria and Multiperiod programming for scenario analysis in Guadalquivir River irrigated farming. *Journal of the Operational Research Society*, 57: 499-509
- Liu, C. M., Li, D. F., Tian, Y., Hao, F. H. and Yang, G. L. 2003. An application study of DEM-based distributed hydrological model on macroscale watershed. *Progress in Geography*, 22 (5): 437–445.
- Luwesi, C. N. 2010. Hydro-economic inventory in a changing environment: An assessment of the efficiency of farming water demand under fluctuating rainfall regimes in semi-arid lands of South-East Kenya. Saarbrücken: Lambert Academic Publishing AG & CO.KG.
- Luwesi, C. N. and Bader, E. 2012. Essentials for implementation of improved Green Water management in Muooni Catchment, Machakos District of Kenya. Proceedings of the 2012 Nile Basin Conference, El Minia, Egypt.
- Luwesi, C. N., Shisanya, C. A. and Obando, J. A. 2011. Towards a hydro-economic approach for risk assessment and mitigation planning for farming water disasters in semi-arid Kenya. In *Risk Management in Environment, Production and Economy*, edited by M. Savino. Rijeka, pp 27-46.

- _____. 2012. Warming and greening: The dilemma facing Green Water economy under changing micro-climatic conditions in Muooni Catchment, Machakos, Kenya. Saarbrücken: Lambert Academic Publishing AG & CO.KG.
- Malesu, M. M., Oduor, A. R. and Odhiambo, O. J. 2007. Green Water management handbook: Rainwater harvesting for agricultural production and ecological sustainability. Nairobi: The World Agroforestry Centre (ICRAF).
- Mcgill, R. 2006. Achieving results: Performance budgeting in the least developed countries. New York: UNCDF.
- Meijerink, G., Muchena, F., Njue, E., Noel, S., Onduru, D. and Porras, I. 2007. Political, institutional and financial framework for Green Water Credits in Kenya. In *Green Water Credits Report 6*, edited by D. Dent. Wageningen: ISRIC-World Soil Information.
- Miller, K. A., Rhodes S. L. and Macdonnell, L. J. 1997. Water allocation in a changing climate: Institutions and adaptation. *Climate Change*, 35: 157-177.
- Mogaka, H., Gichere, S., Davis, R. and Hirji, R. 2006. Climate variability and water resources degradation in Kenya: Improving water resources development and management. The World Bank Working Paper No. 69. Washington, D.C: The International Bank for Reconstruction and Development, The World Bank. Retrieved July 3, 2009, from <http://www.worldbank.org/water>.
- Mukheibir, P. 2008. Water resources management strategies for adaptation to climate-induced impacts in South Africa. *Water Resources Management*, 22: 1259-1276.
- Mumma, A., Lane, M., Kairu, E., Tuinhof, A., and Hirji, R. 2011. Kenya groundwater governance case study. *Water Papers*, June 2011. Washington, D.C: Water Partnership Program, The World Bank. Retrieved June 25, 2012, from <http://www.worldbank.org/water>.
- Ngigi, A. and Macharia, D. 2007. Kenya water sector overview. Nairobi: IT Power East Africa.
- Ngigi, S. N., Savenije, H. G. and Gichuki, F. N. 2005. Land use changes and hydrological impacts related to up-scaling of rainwater harvesting and management in Upper Ewaso Ny'iro Basin, Kenya. Elsevier Ltd., Institute for Water Education DA, Delft.
- Ngonzo, C. L., Shisanya, C. A. and Obando, J. A. 2010. Land use and water demand under a changing climate: Experiences of smallholder farmers from Muooni. In *Climate change*, edited by S. P. Saikia. Jorhat: International Book Distributors, pp. 117-140.
- Nyongesa, J. M. and Muigai, P. 2012. Promoting green development and growth through linking downstream water users to upstream land managers. In *Payment for environmental services-PES scheme in Naivasha Basin, Kenya*.

- Nairobi: WWF Eastern Africa Regional Programme Office and CARE-Kenya.
- OAS. 1991. Primer on natural hazard management in integrated regional development planning. Washington, D.C: Organization of American States (OAS).
- Oduol, J. B. A., Hotta, K., Shinkai, S. and Tsuji, M. 2006. Farm size and productive efficiency: Lessons from smallholder farms in Embu District, Kenya. *Journal of the Faculty of Agriculture*, 51 (2): 449-458.
- Ojwang, J. (2008). Eucalyptus suspected to be causing water shortage in parts of Nile Basin. *Nile News*, 5 (1), January-March 2008, pp 6-7.
- Ortega-Pacheco D. V., Lupi F. and Kaplowitz M. D. 2009. Payment for environmental services: Estimating demand within a tropical watershed. *Journal of Natural Resources Policy Research*, 1 (2): 189–202.
- Pelling, M. 2004. Social capital and institutional adaptation to climate change. *RCC working paper 2*. Liverpool: University of Liverpool.
- Ragab, R. and Hamdy, A. 2004. Water management strategies to combat drought in the semi-arid regions. Retrieved July 3, 2009, from <http://ressources.ciheam.org/om/pdf/b47/05002266.pdf>.
- Reij, C., Tappan, G. and Smale, M. 2009. Re-greening the Sahel: Farmer-led innovation in Burkina Faso and Niger. In *Millions fed*, edited by D. Spielman and R. Pandya-Lorch. Washington, D.C: International Food Policy Research Institute (IFPRI), pp. 53-58.
- Reisner, M. 1993. Cadillac desert: The American west and its disappearing water. New York: Penguin Group (USA) Inc.
- Rietbergen-McCracken, J. and Abaza. 2000. *Environmental evaluation*. London: Earthscan Publications Ltd.
- Rockström, J. 2003. Managing rain for the future. In *Rethinking water management: Innovative approaches to contemporary issues*, edited by C. M. Figueres, C. Tortajada and J. Rockström. London: Earthscan Publications Ltd., pp. 70-101.
- Rockström, J., Falkenmark, M., Karlberg, L., Hoff, H., Rost, S. and Gerten, D. 2009. Future water availability for global food production: The potential of green water for increasing resilience to global change. *Water Resources Research*, 45.
- Rogers, J. W. 2005. A standardized performance assessment and evaluation model for community water systems. PhD thesis, University of Virginia, USA.
- Savenije, H. H. G. and van der Zaag, P. 2002. Water as an economic good and demand management, paradigms with pitfalls. *Water International*, 27 (1), 98-104.

- Scherr, S. J. Wallace, C. And Buck, L. 2011. Agricultural innovation for food security and poverty reduction in the 21st century: Issues for Africa and the world. In *State of the world 2011: Innovations that nourish the planet*, edited by Ecoagriculture Partners. Washington, D.C.
- Sehring, J. 2008. The pitfalls of irrigation water pricing in Kyrgyzstan. *Development*, 51: 130-134.
- Smyth, A. W., Altay, G., Deodatis, G., Erdik, M., Franco, G., Gukan, P., Kunreuther, H., Lus, H., Mete, E., Seeber, N. and Yuzugullu, O. 2004. Probabilistic benefit-cost analysis for earthquake damage mitigation: Evaluating measures for apartment houses in Turkey. *EERI Earthquake Spectra*, 20 (1): 171-203.
- Shakya, N. M. 2001. Impact of forest clearing on hydrology: Mathematical modelling of Khageri River. In *Ecohydrology*, edited by V. Subramanian and A. Ramanathan. New Delhi: Capital Publishing Company, pp. 355-368.
- Shisanya, C. A. 2005. An analysis of accessibility and pricing of water supply in rural watersheds: A case study of Kakamega District, Kenya. *FWU Water Resource Publications*, 5: 161-172.
- Steinemann, A., Hayes, M. J. and Cavalcanti, L. 2005. Drought indicators and triggers. In *Drought and water crises: Science, technology, and management issues*, edited by D. Wilhite. New York: Marcel Dekker. Retrieved February 23, 2011, from <http://water.washington.edu/research/Reports/droughtindicatorsandtriggerschapter.pdf>
- Stephenson, D. 2005. *Water services management*. London: IWA Publishing.
- Stern, N. 2007. *Economics of climate change: The stern review*. Cambridge: Cambridge University Press.
- Subramanian, V. 2001. Water quality and quantity. In *Ecohydrology*, edited by V. Subramanian and Al Ramanathan. New Delhi: Capital Publishing Company, pp. 241-264.
- Terer, J. 2004. *The study of hydrologic characteristics and management practices in agricultural river catchments: The case of Nyorongores River Catchment, Mara River Basin, Kenya*. Nairobi: ACTS Press.
- Tiffen, M. and Mortimore, M. 2002. Agroecosystems regaining the high ground: Reviving the Hillsides of Machakos. *World Resources 2000-2001*, pp. 149-158.
- Tiffen, M., Morimore, M. and Gichuki, F. 1994. More people, less erosion: Environmental recovery in Kenya. Nairobi: ACTS Press.
- UNEP. 2011. Towards a green economy: Pathways to sustainable development and poverty eradication. Retrieved June 25, 2012, from www.unep.org/greeneconomy

- van Aalst, M. K. 2006. The impacts of climate change on risk of natural disasters. *Disasters*, 30, 5-18.
- Venkatachalam, L. 2003. The contingent valuation method: a review. *Environmental Impact Assessment Review*, 24: 89–124
- Wilschut, L. I. 2010. Land use in the Upper Tana: Technical report of a remote sensing-based land use map. In *Green Water Credits Report 9*, edited by B. Macmillan, S. Kauffmann and R. de Jon. Wageningen: ISRIC-World Soil Information.
- World Bank et al., AfDB, FAO, IFAD and IWMI. 2008. *Investment in agricultural water for poverty reduction and economic growth in Sub-Saharan Africa: A synthesis report*. Washington, D.C: The World Bank.
- Wunder, S. 2007. The efficiency of payments for environmental services in tropical conservation. *Conservation Biology*, 21 (1): 48-58.
- Zhang, Y., Grant, A., Sharma, A., Chen, D. and Chen, L. 2010. Alternative water resources for rural residential development in Western Australia. *Water Resources Management*, 24: 25-36.

Drivers for Adoption of Water Harvesting Technologies in Uganda With Reference to Lira District in Northern Region

Tobias Onweng

Abstract: Despite the availability of abundant water resources, most farming households in Lira District still depend on rain for agricultural production. While policies for water (1999) and agriculture (2011) support water use for production, they have not been effectively implemented. Most farming households have therefore to depend on innovative water harvesting technologies to produce food and obtain income throughout the year. The overall objective of the research was to analyze the factors that drive farmers' adoption decisions related to innovative water harvesting technologies in the district. Data was collected from random samples of households using household interviews, focus group discussions and key informant interviews. The research found that the main innovative water harvesting technologies used were furrow and ridge irrigation, drip irrigation, surface water tanks, underground water tanks, and fish ponds, to a limited extent. Farmers' experience of the technology and perception of the characteristics of the technology were main drivers of adoption decisions. Farmers' experiences, low cost of the technology, potential for income and simplicity of technologies had more influence on adoption of furrow and ridge irrigation than drip irrigation, surface water tanks, underground water tanks, and fish ponds. Availability of technical service and financial resources influenced the decisions to use drip irrigation, underground water tanks and fish ponds more than the use of furrow and ridge irrigation. The research recommended dissemination of furrow and ridge irrigation, drip irrigation and surface water tanks using low cost materials, and the provision of technical service and training of farmers to promote acceptability as well as adoption and use of these technologies.

Key words: Drivers, technology adoption, water harvesting technology, furrow and ridge irrigation, drip irrigation, surface water tanks, underground water tanks, and fish ponds.

1. Introduction

1.1 Background

Although agriculture is the mainstay of the economy of Uganda, contributing 49 per cent of GDP and employing over 80 per cent of the population, food security and financial benefits to farmers are still major issues (Ministry of Water Lands and Environment, (MWLE) 1999). A key

reason is the dependence on rainfed agriculture. Although the country has abundant water resources, it is unevenly distributed in time and space. The situation is exacerbated by lack of effective implementation of water supply policies for agricultural production. In dry areas, surface water resources are generally seasonal and groundwater potential is often limited. In many cases, dams and valley tanks have insufficient flow or lack the storage capacity to prevent them from drying out (MWLE 1999). In view of the limited spread of open water bodies (lakes), there is need to develop aquaculture, to provide fisheries resources for vital protein intake for the increasing population, and for export (MWLE 1999). Development of water resources to supplement rainfed agriculture could increase the overall crop, livestock and fish production, through increasing cropping intensity, forage production and reliable livestock water, especially in the semi-arid and drought prone areas.

Due to limited development of water for production, farming households have to depend on innovative technologies for harvesting water but the use of these innovative water harvesting technologies is limited, and the factors that influence their adoption were not clear. This research investigated the major drivers for adoption of water harvesting technologies.

Section one consists of the problem statement, which presents research objectives and methodologies used. Section two presents the relevant literature and conceptual framework. Results and discussions are presented in section three. The last section discusses the conclusions and recommendations of the research.

1.2 Problem Statement

Persistent seasonal household food shortages and low income affect a majority of farming households in Uganda. The situation is worse in Lira District, in Northern Uganda. Despite the availability of abundant water resources, most farmers still depend on rainfed agriculture, limiting production to only wet months of the year. The available water resources are not adequately tapped for production of crops and livestock. The existence of policies that support water use for production is implemented to a limited extent. Farming households have, therefore, to depend on innovative technologies for harvesting water for production. The use of these innovative water harvesting technologies is limited. It is not clear what factors influence the adoption of these water harvesting technologies. Available literature on water use in Uganda did not adequately analyze factors that influence adoption of water harvesting technologies (FAO 2005; Tayebwa 2008; UNWP and IUCN 1998; Dai Rais 2005; and UWASNET 2001).

Studies that have attempted to examine the drivers of adoption of water harvesting technologies (Hatibu and Mahoo n.d) did not analyze these drivers in detail. Another research study on rainwater harvesting in Western Uganda did not describe the characteristics of households that tap rainwater

using tanks (Dai Rais 2005) to enable an understanding of what influenced the decisions of households to use this technology. A study on fish ponds neither presented the socioeconomic characteristics of the farmers that benefitted from fish production using fish ponds nor did it analyze the variables that influenced them to use the fish pond technology (Tayebwa 2008).

Hardly any data is available on innovative water harvesting technologies in Lira District. In addition, hardly any research has been conducted on the costs and benefits of innovative water harvesting technologies. There is neither data on the factors that influence adoption decisions by farmers nor an assessment of the impact of water harvesting technologies on the livelihoods and living conditions of the people in Lira District.

The research therefore analyzed the main factors that influenced the decisions of farmers to choose water harvesting technologies, focusing on Lira District and guided by the following questions:

- i. What types of water harvesting technologies are used in the district?
- ii. What factors influence farmers' decisions to adopt innovative water harvesting technologies?
- iii. What is the impact of water harvesting technologies on living conditions?

1.3 Research Objective

The overall objective of the research was to describe the water harvesting technologies and analyze the factors that influenced farmers' adoption decisions. Specifically, the research described the water harvesting technologies in the district, analyzed the factors that influence farmers' decisions to adopt innovative water harvesting technologies, and assessed the impact of water harvesting technologies on the living conditions of communities.

1.4 Methodology

1.4.1 Research Area

Lira District is located in Lango sub-region in central-northern Uganda, and falls within the Lango farming subsystem that consists of eight districts, namely Lira, Alebtong, Otuke, Dokolo, Amolatar, Kole, Oyam, and Apac. The Lango farming subsystem is described as an annual cropping and cattle northern system (traditionally predominantly cattle-keeping area in Northern Uganda). The farming system is between 975 metres and 1,145 metres above sea level (masl) and receives bimodal rainfall, ranging from 1,000 millimetres to 1,500 millimetres per annum. The area is generally hot with temperatures over 25°C. Vegetation is dominated by tall tree grassland savanna, with shrubs and thickets permeated by some woodlands (Brin et al. 2002). The total population is 280,600 persons with a density of 79 persons per square

kilometer and is predominantly rural, with just under 5 per cent living in urban areas. The farming subsystem lie in the poorest regions of the country (Brin et al. 2002). Agriculture is the main economic activity in the district comprising crops, vegetables, fruits and livestock and fish (Brin et al. 2002). Civil unrest resulted in the decline of the cattle population and loss of productive assets both for income and draught power (animal traction). The use of external inputs (seeds and soil amendments) is constrained by prohibitive costs and availability of these inputs, which stems from the ineffectiveness of the existing extension system and a weak private sector base (Brin et al. 2002). Abundant water resources, if developed, would provide an a vital opportunity for the district to recover from the civil conflicts and boost household food security and incomes.

1.4.2 Research Design and Sampling

Lira District was purposively selected because of its drought prone characteristics and the effects that the civil strife had on food security, household incomes and overall quality of life. A cross-sectional design and multi-stage sampling procedure was used to randomly select sub-counties, parishes, villages and households. From each village, the first sample was randomly selected from the left of a path that runs across the village, while the second sample was the third household selected following an odd interval, until 176 households had been selected. Five groups consisting of farmers were selected for focus group discussions, four from rural sub-counties and one from the peri-urban area, with each focus group consisting of an average of 10 participants, comprising both men and women. Four officials in the district of the study were purposively selected, who included officers responsible for water, agriculture, veterinary services, and fisheries, and one official from the National Agricultural Research Organization (NARO).

1.4.3 Data Collection and Analysis Methods

Data was collected using household interviews, focus group discussions and key informant interviews as described below. The household interview was conducted with household heads or any adult person who could provide information on household water use patterns and factors driving the choice of water harvesting technology. Semi-structured, face-to-face interview schedules were used to collect household data. Focus group discussions were conducted by two persons, one facilitator and one recorder, using a focus group topic guide. Key informant interviews were held with four district local government officials and one official from NARO. Ethical procedures were followed in the process of data collection. All respondents were informed of the research, its purpose and potential benefits. Based on their knowledge of the research, consent was sought from the participants to engage in the study. Data was analyzed depending on the methods used for collection. Qualitative data was analyzed using content analysis technique, based on a matrix of issues and responses. In regard to quantitative data, a template for data analysis was developed in SPSS Data Analysis Programme. Completed household interview schedules were edited while open-ended interviews were

coded. Data were entered into a data-entry template and data sets were produced, cleaned and analyzed, using frequencies and percentages.

2. Literature Review

2.1 Introduction

A fairly good volume of literature is available on the factors that drive the adoption of water harvesting technology for production. The review focuses on studies that highlight the use of water harvesting technologies for production and key factors that have influenced their adoption.

2.2 Water Harvesting Systems

Several researches have documented various forms of rainwater harvesting used traditionally throughout the centuries. Some of the earliest agricultural activities in the Middle East were based on technologies such as diversion of *wadi* flow into agricultural fields. Other examples include the Nagev Desert (Evanari et.al. 1971), the desert areas of Arizona and Northwest Mexico (Zaunderer and Hutchinson 1988) and South Tunisia (Pacey and Cullies 1986). The importance of traditional, small-scale systems of rainwater harvesting in Sub-Saharan Africa has recently been recognized (Critchley and Reij 1989). For instance, simple lines are used in Burkina Faso and Mali, while earth bunding systems are used in Eastern Sudan, Kenya and the central rangelands of Somalia. The potential for water harvesting, for improved crop production, received great attention in the 1970s and 1980s. This was due to the widespread droughts in Africa, which left a trail of crop failures and a serious threat to humans and livestock. Consequently, a number of water harvesting projects were set up in Sub-Saharan Africa. The main objectives were to combat the effects of drought by improving plant production in some areas and rehabilitating abandoned and degraded land (Critchley and Reij 1989). However, a few of the projects have succeeded in combining technical efficiency with low costs and acceptability of water harvesting technologies by local farmers or agro-pastoralists. This was partly due to the lack of technical know-how but also often due to the selection of an inappropriate approach with regard to prevailing socioeconomic conditions.

A study has revealed that water harvesting technologies have not received technical support. A study in Dodoma and other parts of Tanzania, for instance, revealed that water harvesting systems preferred and practised by farmers have not received enough technical support mainly because they operate outside formal projects. This may be due to lack of an effective regional policy and strategy geared towards the development of various systems for crop production (Hatibu and Mahoo n.d). The same study found that individually based water conservation and harvesting systems, to a large extent, have been more successful than collective-based systems. Communally owned systems such as rainwater harvesting storage

reservoirs were found to suffer from lack of protection, care and maintenance (Hatibu and Mahoo n.d).

The importance of surface tank technology in tapping rainwater for domestic use was highlighted by a research in Western Uganda. A study in Kabarole District, in Western Uganda, showed that with just 12 rainy days in two months during the dry season, a family of five could obtain 60 per cent of all their household water from a tank – a total of 118 jerricans (of 20 litres each). If their traditional water source was 500 metres away, in two months they would save nearly 50 hours of their time by using the water tank. A study in Western Uganda showed that up to 70 per cent or 80 per cent of household water needs can be met with small rainwater jars. Rainwater harvesting works best when rainfall is fairly regular throughout the year (Dai Rais 2005). The study in Kabarole District did not show what categories of households could afford a surface tank for harvesting rainwater to enable an understanding of the extent to which poor households could access the tank for tapping rainwater for domestic use, to support activities such as vegetable growing, goat rearing, piggyery, and poultry keeping. In addition, it did not indicate the nature of the tanks – whether they were plastic, brick or cement tanks. Furthermore, the study did not assess the extent of durability of the water tank.

A study revealed that fish ponds were a profitable technology that contributed to poverty reduction. Tayebwa (2008) found that fish ponds were better alternatives to swamps because they do not involve draining of water in swamps. Instead ponds retain all the water. Because of the growing demand of fish in Uganda and other countries the study noted that there was over fishing of natural lakes leading to catching of immature fish. The fish ponds therefore reduce the stress imposed on natural lakes, which is likely to lead to extinction of some fish species. The study further found that fish farming was a profitable business compared to other enterprises and was, therefore, seen as a way of reducing poverty in rural areas by increasing farmers' incomes. Fish farming was found to be a viable enterprise that ensures sustainable use of wetlands and provides a constant flow of income to the farmers (Tayebwa 2008). While the study showed that fish ponds are a profitable business that would contribute to poverty reduction, it did not indicate the socioeconomic characteristics of farmers engaged in fish production, those using the fish pond technology and the factors that influence decisions to adopt them.

2.3 Factors Influencing Adoption of Water Harvesting Technologies

Several studies have revealed the factors that influence adoption of water harvesting technologies (Hatibu and Maho n.d, Drechsel at al. n.d and Jagger and Pender n.d). Hatibu and Maho (n.d) found that potential for increasing cash income is a big factor affecting the adoption of rainwater harvesting in Dodoma. It was noted, for example, that where it has been adopted, rainwater harvesting is used for the production of maize, paddy rice and vegetable crops that can be sold for cash. In addition, from the

socioeconomic stand point, the potential is high because where clear benefits have been demonstrated, farmers have shown a willingness to undertake, at their own initiative, huge capital investment in rainwater harvesting. Examples include purchasing tractors to attain deep tillage and construction of bunds for paddy rice production. Finally, the study showed that villagers have been using water collected in natural depressions or manmade reservoirs but have shown very little interest in adopting this technology. This is because although the benefits of the technology been very well demonstrated in Dodoma, very few individuals or villagers have adopted the technology to construct their own reservoirs. Where one has been built, people simply use the water until the reservoir dries, without considering the possibility of increasing water availability by constructing more reservoirs or expanding existing ones.

Raffler and Naugle (n.d) pointed out the importance of affordability and acceptability as drivers of adoption of the technologies. They indicated that a newly developed rainwater storage device (RSD) to be introduced in Uganda by Relief International, offers a promising technological solution to the twin problems of insufficient quantities of water and poor quality. Water of inadequate quantity and quality hinders human capabilities throughout the developing world, and the success of the rainwater storage device can, therefore, have welfare consequences on a global scale. However, new technologies are only useful to the extent that they are affordable for, and acceptable to, intended beneficiaries. Low demand for many different types of technologies, seemingly capable of improving welfare, is a central puzzle in development. Several examples span sectors, ranging from agricultural inputs (high-yield varieties and fertilizer) to household health technologies (insecticide treated bed-nets) and point-of-use drinking water treatments.

A research by Drechsel et al. (n.d) revealed that adoption of water harvesting and conservation technology is a function of the characteristics of the technology proposed, farmers' perception of advantages and need, as well as availability and distribution of production factors (land, labour, time, capital, knowledge, and skills). Other factors include farmers' attitude towards experiments, perceived risks, institutional support/knowledge sharing, and the policy environment.

A research by Jagger and Pender (n.d) found that in Uganda, aquaculture is a potential pathway to development for rural smallholders, the landless, and marginalized groups, including women. Aquaculture may reduce poverty and contribute to sustainable land use by improving food security, providing rural employment, contributing to regional economic growth, and diversifying smallholder-farming systems. Jagger and Pender (n.d) hypothesized that there are conditions, including land quality, population density and access to input and output markets, under which pond aquaculture is likely to be most successful. Aquaculture may have its greatest potential in regions where the adoption of fish ponds provides an

environmentally preferable livelihood strategy to draining and farming wetlands. Land areas with gullies and ditches that can support fish ponds, and regions where land is generally not scarce, may also be well suited to fish ponds. Aquaculture is relatively labour intense, indicating that regions with moderate or high population densities, relatively low wage rates and few off-farm labour opportunities will be best suited to its development (Jagger and Pender n.d).

Although the majority of fish production in Uganda is currently derived from lake fisheries rather than aquaculture ponds, the presence of an established market for fish and fish products is illustrative of clear consumer preferences for fish and fish products, indicating sufficient demand to support aquaculture enterprises in many, although not all regions of the country. There are technical, institutional and social constraints to the sustainable adoption of aquaculture technologies in Uganda. Firstly, as is the case throughout most of Sub-Saharan Africa, aquaculture in Uganda is a non-traditional technology; Sub-Saharan Africa currently accounts for less than 0.2 per cent of world aquaculture production. Secondly, the limited extent of Ugandan aquaculture indicates the need for education and technical training, and the integration of aquaculture into agricultural extension portfolios. The complex relationship between livestock and aquaculture systems provides an example of the degree of specialized knowledge that smallholder farmers require to effectively co-manage fish ponds and livestock that provide a source of manure for fertilizing ponds. Thirdly, the availability of suitable land, water, labour and inputs such as fish feed, may also be primary production constraints. The critical importance of institutional stability, including access to credit and tenure security, and the development of post-harvest technologies and transportation systems that can support the delivery of fish products to markets were also considered (Jagger and Pender n.d).

2.4 Conclusions

The studies described traditional water harvesting technologies for tapping water resources, for various uses. The literature further focused on current technologies for tapping water for crop and fish production and the factors that influence the decisions to use these technologies, including affordability and acceptability; potential for increasing cash income; technical, institutional and social constraints; availability of factors of production such as suitable land, tenure security, water, and labour; other inputs such as credit and post-harvest technology; and transport systems. The research, however, did not provide a detailed analysis of the factors that drive each of the water harvesting technologies. The current study attempted to fill this gap.

2.5 Conceptual Framework

The study assumed that the adoption of innovative water harvesting technologies was dependent on several factors, including farmers' experience

of the technology through observation, trials or test; perceived characteristics of the technology such as cost, benefits or potential for income generation, and technical complexity; and institutional and social factors.

2.5.1 Farmers' Experience of the Technology

Farmers' experience of the technology is through trial or test of the technology. If a farmer has actually experienced the technology, then he/she is likely to adopt it if no constraints to its adoption were experienced. But where constraints to adoption were experienced, the farmers is unlikely to adopt the technology.

2.5.2 Perception of the Technology (Complexity, Cost and Benefits)

The simpler the technology to use, the more likely it is to be adopted. The higher the complexity of the technology, the less likely it is to be used. In addition, the lower the cost of the technology, the higher the likelihood of it being adopted. If the farmers perceive the impact of the technology to be obvious (contribution to income generation is easily seen and is convincing), then the technology is likely to be used.

2.5.3 Institutional and Social Factors

If the technology is perceived to be trouble-free, without institutional and social difficulties experienced in using the technology, then farmers will opt to use it. On the other hand, if these difficulties are perceived by farmers, the technology is less likely to be adopted. Institutional factors such as land tenure regime also influence the use of technology by farmers. Where the land does not belong to farmers, fish ponds may not be constructed and used for fish farming as it is a long-term investment, which is possible only if farmers own the land. Certain technologies are easier to apply, in relation to social factors, such as where population is sparse, and more difficult to apply in areas with a dense population. For example, the construction of surface tanks is more likely in a sparsely populated area than in a densely populated area. Another social factor is the existence of abundant labour, which would influence the adoption of drip irrigation that requires abundant labour to initiate and operate. Where limited labour is available, adoption of drip irrigation is less likely to occur. Similarly, where the population engages in group farming, the fish pond is likely to be adopted as operations such as digging of the pond and feeding the fish become easier to manage due to labour availability. The adoption of the innovative water harvesting technology was assumed to result in improved living conditions of farming households.

3. Results and Discussion

3.1 Respondents' Profiles

Data were collected from 176 respondents, about two-thirds (64 per cent) of whom were household heads and one-fifth (20 per cent) were spouses. In addition, about one-third (63.3 per cent) were male, and four in ten were

female (36.9 per cent), reflecting the gender distribution of household heads in the study district. Respondents ranged in age from 18 to 65 years, with a relative majority (37.7 per cent) aged between 26 and 35 years. Most respondents were full-time farmers (65.3 per cent), one-fifth were traders practicing farming (19.9 per cent) and only 5.7 per cent were civil servants. Civil servants increasingly invest in farming as a risk reduction strategy against loss of employment. This is the category of respondents who have the financial capacity to invest in fish ponds and drip irrigation, while a majority of farmers were engaged in furrow and ridge irrigation that did not require heavy investment. Two-thirds of the respondents had attained primary education (61.7 per cent), one-fifth attained secondary education (19.1 per cent) and one-tenth obtained vocational training (9.2 per cent).

3.2 Types of Water Harvesting Technologies in the Research District

Furrow and ridge irrigation were used by a majority of farmers (69.1 per cent), drip irrigation (8 per cent) and surface water tanks (8 per cent) were used to a limited extent, underground water tanks (1.7 per cent) and fish ponds (2.9 per cent) were used by a negligible percentage of farmers as shown in Table 1 below.

Table 1. Water harvesting technologies used

Water harvesting technologies	Frequency	Percentage
Drip irrigation	14	8
Furrow and ridge irrigation	121	69.1
Surface water tanks	14	8
Underground water tanks	3	1.7
Fish ponds	5	2.9
Others	18	10.3
Total	175	100

SOURCE: Primary data

Furrow and ridge irrigation involved digging furrows in the swamp or dry land, and heaping the soil on both sides of the furrow to form a ridge. The furrows facilitate the flow of water within the swamps, or rainwater on dry field, and crops are planted on the ridge, kept moist by water flowing in the furrows. Drip irrigation, on the other hand, involved the application of used water bottles that are placed above the roots of crops, and a hole is made at the bottom of the bottle, to allow water to be slowly released to the roots of the crops. Another method of delivering water to the roots of plants is by tying the bottle upside-down to a stick sunk into the ground, close to the plant, with the bottle pointing to the roots. Water poured through the cut bottom of the bottle slowly flows to the plant roots through a hole in the bottle top. Instead of a bottle, a funnel shaped polythene paper may be tied on a stick just above the roots of each plant. Furthermore, surface water

tanks can be made of bricks, metal or plastic materials of different sizes, ranging from 50 to 50,000 litres. These are placed on the verandah of a building, below the rainwater gutter. Rainwater falls into the tank and can be used for vegetable growing, livestock and poultry rearing, among others. Underground tanks on the other hand, were in the form of a rectangular hole dug in the ground and strengthened with concrete and cement, or a polythene paper, used to cover the bottom and sides of the hole. A channel leading to the underground tank is dug to facilitate the flow of rainwater into the tank. Finally, construction of fish ponds by a negligible percentage of households (2.9 per cent) was undertaken both by groups and individuals. However, most of the fish ponds in the district belonged to groups supported by World Food Programme (WFP), Food and Agricultural Organization (FAO), and Northern Uganda Social Action Fund (NUSAF). A few individuals had fish ponds.

3.3 Uses of Water

Water was mainly used for growing of crops, rearing of livestock and domestic use. Commodities produced included crops (91.5 per cent), vegetables (63.6 per cent), fruits (38.6 per cent), livestock (47.2 per cent), poultry (51.7 per cent) and fish (5.1 per cent). The main crops produced included beans (37.4 per cent), maize (27.7 per cent) and rice (26.5 per cent). Other crops included cassava (4.5 per cent), sweet potatoes (1.3 per cent), sorghum (0.6 per cent) and sesame (0.6 per cent). The main types of fruits grown included oranges (51.4 per cent) and mangoes (37.1 per cent). Bananas (3.8 per cent), pawpaws (3.8 per cent) and avocados (1 per cent) were grown by just a few households. Vegetables were produced by households living close to wetlands, mainly during the dry season, due to availability of water for consumption and income. The main types of livestock reared comprised of cattle (80.4 per cent), poultry (51.7 per cent), goats (18.6 per cent) and pigs (1 per cent). Cattle and goats do well, in both wet and dry seasons.

Rainwater tapped in surface and underground tanks during wet months was stored and used to water small livestock such as goats and pigs as well as chicken during dry months. While furrow and ridge irrigation was used for growing of vegetables, drip irrigation was used for growing fruits such as oranges and mangoes, mainly for the market.

Modern fish production using fish ponds was very limited among households in the district because of the high costs involved, which entailed construction of fish ponds, purchase of fingerlings and fish feeds, and providing security to keep thieves away. The research results show that a few farmers were engaged in fish farming and these included civil servants and business dealers who could afford the construction and management costs. A few groups of farmers were also found to produce fish with the support of the government's NUSAF, UN WFP, FAO, and nongovernmental organizations (NGOs).

3.4 Factors Driving Adoption of Water Harvesting Facilities

The main drivers for adoption of water harvesting technologies included farmers' experience of the technology, perception of the characteristics of the technology (complexity, cost and benefits), and to some extent, potential for income. Institutional and social factors did not have a significant influence on farmers' decision to adopt the technology as shown in Table 2 below.

Table 2. Drivers of technology adoption

Drivers	Frequencies	Percentages
Farmers' experience with the technology	114	65.1
Perception of the technology	42	24
Potential for income	8	4.6
institutional and social factors	4	2.3
Total	168	100

SOURCE: Primary data

Technologies that farmers had experience through trial or testing, such as furrow and ridge irrigation, were more likely to be adopted than the ones that the farmers had no prior experience of, hence required technical service. In addition, technologies that the farmers perceived to be of low cost, such as furrow and ridge irrigation and surface water tanks, were more likely to be adopted than those that were perceived to be of high , such as drip irrigation, fish ponds and underground tanks, and therefore, not affordable for most poor farmers. These results tally with a report by Raffler and Naugle (n.d) which indicated that although a newly developed rainwater storage device to be introduced in Uganda by Relief International offers a promising technological solution to the twin problems of lack of access to water in sufficient quantities and of sufficient quality, new technologies are only useful to the extent that they are affordable and acceptable to the intended beneficiaries. Low demand for many different types of technologies seemingly capable of increasing welfare is a central puzzle in development. Several examples span sectors, ranging from agricultural inputs (high-yield varieties and fertilizer) to household health technologies (insecticide treated bed nets) and point-of-use drinking water treatments. This has mainly been because few of the projects have succeeded in combining technical efficiency with low cost and acceptability to local farmers or agro-pastoralists. This was partly due to lack of technical know-how, but also often due to the selection of inappropriate approaches with regard to the prevailing socioeconomic conditions (Critchley and Reij 1989).

Furthermore, technologies that were perceived to generate income, such as furrow and ridge irrigation, and drip irrigation, had more chances of being

adopted than those that were not perceived to generate income. Further, the level of complexity of the technology either facilitated or constrained ease of technology operation and adoption. Technologies perceived to be simple to use, such as furrow and ridge irrigation, were more likely to be adopted than the more complex technologies such as drip irrigation and underground tanks. The more the technology was perceived to have an impact, the more likely it was to be adopted. This is consistent with findings of a research by Drechsel et al. (n.d.), which revealed that adoption of water harvesting and conservation technology is a function of the characteristics of the technology proposed, farmers' perception of advantages and need, as well as availability and distribution of production factors (land, labour, time, capital, knowledge, and skills). Other factors are farmers' attitude towards experiments, risk, institutional support/knowledge sharing, and the policy environment.

The drivers were found to counteract each other's influence on farmers' decisions. For example, while experience of the technology motivates a farmer to adopt a technology such as drip irrigation, the high cost of establishing the technology as well as operational costs discourage the farmer from adoption. In addition, while perception of benefits (income) from a technology, such as fish pond, would encourage a farmer to adopt it, the high cost of construction and operational costs constrain adoption. The research found that institutional and social factors did not have any significant influence on the decision of farmers to use the technologies.

In the subsequent paragraphs, findings on factors that influenced adoption of each of the water harvesting technologies are discussed.

3.4.1 Factors Influencing Decision to Use Drip Irrigation

Of the 8 per cent of respondents who reported using drip irrigation, nearly eight in ten (78 per cent) were influenced to use drip irrigation technology because the farmer had experience of it through observation and testing, making it easier to adopt, in contrast to only 14.3 per cent who preferred drip irrigation because it was perceived to be simple to operate, and a small percentage of 7.1 per cent used the technology because of its potential for income generation. Institutional and social factors did not have any influence on the farmer's decision to use the technology. Table 3 below shows the responses in regard to the factors influencing decisions of farmers to use the technology.

Table 3. Factors influencing adoption of drip irrigation

Drivers	Frequency	Percentage
Experience of the technology	11	78.6
Perception of the technology	2	14.3
Potential for income	1	7.1
Cultural, physical, institutional, demographic, gender and social factors	0	0
Total	14	100

SOURCE: Primary data

Adoption of drip irrigation was low because it was difficult to adopt and operate. Its costly character involved tying water bottles or bottle-shaped polythene papers above the roots of every plant, a tedious task, and regularly refilling the bottle with water drawn from a water source, that in some cases was located a considerable distance away. The tedious process of transporting and pouring water into the bottle made the operation difficult. A few farmers had the financial resources to adopt the technology and manage operations. Compared to other technologies, drip irrigation was the most expensive, requiring an average of Uganda shillings 3,406,923 per acre of land, compared to the cost of furrow and ridge irrigation at an average of Uganda shillings 311,291 per acre, one-tenth of the cost of drip irrigation. The high cost of the technology was a key factor explaining the adoption of drip irrigation by just a few households.

3.4.2 Factors Influencing Use of Furrow and Ridge Irrigation

Of the 69.1 per cent who reported using furrow and ridge irrigation, two-thirds (64.5 per cent) were influenced by the experience of the technology, making it easy to adopt, followed by nearly one-third of respondents who used the technology because they perceived it to be simple to operate, as depicted in Table 4 below.

Table 4. Factors driving adoption of furrow and ridge irrigation

Drivers	Frequency	Percentage
Experience of the technology	78	64.5
Perception of the technology	34	28.9
Potential for income	6	4.95
institutional, and social factors	1	0.8
Others	2	1.65
Total	121	100

SOURCE: Primary data

Intra-technology comparison of driving factors revealed that most respondents (64.5 per cent) were influenced to use furrow and ridge irrigation because they had experienced the technology, compared to the perception that the technology was simple to operate, as reported by one-third of the respondents (28.9 per cent), while about 5 per cent were influenced to use the technology because of the potential for income. This result confirmed the findings of a research by Hatibu and Mahoo (n.d) that revealed that the potential for increasing cash income is a big factor affecting the adoption of rainwater harvesting in Dodoma. It was noted, for example, that where it has been adopted, rainwater harvesting is used for the production of maize, paddy rice and vegetables — crops that can be sold for cash. In addition, from the socioeconomic standpoint the potential is high because where clear benefits have been demonstrated, farmers have been ready to undertake, at their own initiative, huge capital investment in rainwater harvesting. Examples include purchasing tractors to attain deep tillage and construction of bunds for paddy rice production.

For most farmers, furrow and ridge irrigation involved using physical labour to construct and operate but did not require the use of a petrol/diesel engine or electric power to propel, which would have been financially prohibitive to a majority of farmers. The technology was also of low cost, and therefore, affordable for nearly all farming households. For one-third of respondents, its simplicity made it easy to operate, thereby influencing their decision to use furrow and ridge irrigation, and did not require elaborate technical service. In fact, some respondents reported that operating the technology did not require education, and even in the absence of technical education, farmers could use the technology.

The availability of extension services to farmers for using the technology was not a major driver for adoption and operation of furrow and ridge irrigation. This was reflected by the fact that regardless of only one-fifth of respondents obtaining extension services, the technology was still adopted. District technical officials also confirmed findings from household respondents by indicating that furrow and ridge irrigation was used by many farmers because it was easy to construct and manage, and the potential of getting income from horticultural crops during the dry season encouraged adoption. Furrow and ridge irrigation was, therefore, used by most households, compared to other technologies such as surface water tanks, underground water tanks, drip irrigation, and fish ponds, because of its comparative advantage of being simple to use, easy to try on a small-scale without technical advice, and its impact was visible, obvious and convincing, in terms of income earning horticultural crops.

3.4.3 Drivers for Use of Surface Water Tanks

Of the 8 per cent of respondents who reported using surface water tanks, 85.7 per cent were driven by the experience of the technology in contrast to only 7.14 per cent who were driven to use because it was simple to operate,

and another 7.14 per cent because it did not have institutional and social constraints as shown in the Table 5 below.

Table 5. Factors driving use of surface water tanks

Drivers	Frequency	Percentages
Experience of the technology	12	85.7
Perception of the technology	1	7.14
Potential for income	0	0
institutional, social factors	1	7.14
Others	0	0
Total	14	100

SOURCE: Primary data

Adoption of surface water tanks in the research district was low. Although some farmers adopted surface water tanks due to the experience of the technology, the perception of the simplicity of the technology and factors such as institutional and social factors did not have any significant influence on the decisions of respondents to adopt the technology. Potential for income did not have any influence on adoption of the technology. The study by Hatiboo and Mahoo (n.d) showed low adoption of rainwater harvesting technology. Villagers have been using water collected in natural depressions or manmade reservoirs but have shown very little interest in adopting this technology. Although the benefits of the technology have been very well demonstrated in Dodoma, very few individuals or villagers have adopted the construction of their own reservoirs. Where one has been built, people simply use the water until it the reservoir dries, without considering the possibility of increasing water availability by constructing more reservoirs or expanding existing ones.

3.4.4 Factors Influencing Use of Underground Water Tanks

Of the 1.7 per cent of respondents who reported using underground water tanks, more than two-thirds were driven to adopt underground tanks by experience of the technology compared to more than one-third who were driven by the perception of that the technology was easy to operate, as Table 6 shows.

Table 6. Factors influencing use of underground water tanks

Drivers	Frequency	Percentages
Experience of technology	2	66.66
Perception of technology	1	33.33
Potential for income	0	0
Cultural, physical, institutional, demographic, gender and social factors	0	0
Others	0	0
Total	3	100

SOURCE: Primary data

Low adoption of underground water tanks was due to the high cost of construction and lack of potential for income generation. Institutional and social factors did not have any influence on adoption and use of underground water technology. Only a few farmers, of means, were able to afford this water harvesting technology as the construction was found to be costly, and therefore, not affordable for most farmers with relatively low incomes.

2.4.5 Factors Influencing Use of Fish Ponds

Of the few 2.9 per cent who reported using fish ponds, two-thirds were influenced by the perception that it was less complex and less costly to operate, compared to 40 per cent who were motivated by experience of the technology as shown in Table 7.

Table 7. Factors influencing use of fish ponds

Drivers	Frequency	Percentages
Experience of technology	2	40
Perception of technology (complexity and cost)	3	60
Potential for income	0	0
Cultural, physical, institutional, demographic, gender and social factors	0	0
Others	0	0
Total	5	100

SOURCE: Primary data

Overall, the low adoption of fish pond technology was due to the high cost of construction and operation. The construction was undertaken by a few people with financial resources who could afford to meet construction costs, and pay for technical services and operations. Fish ponds had the second highest average cost of Uganda shillings 920,000, compared to

other technologies. Factors such as potential for income, and institutional and social factors had no influence on adoption of fish ponds. The construction of ponds was a function of capital and extension services. This explains why only 10 households were found to be involved in the enterprise.

The high cost of construction of fish ponds, the difficulty in obtaining fish for stocking due to lack of fish hatcheries in Lira District and the whole of Northern Uganda (one has to get stock from Kampala, about six hours drive from Lira town), severely constrained adoption by most farmers. In addition, while women were heavily involved in the management of fish ponds, in terms of feeding the fish, the men controlled harvesting, selling and income. This has made restocking difficult because fish pond management requires that some money earned be ploughed back after sale of fish, for restocking, but the men never plough back the money, leading to collapse of the enterprise. Donors funded the construction of fish ponds and start-up feeds while the communities were responsible for the management of the ponds. Weak group organization and poor management due to low levels of education and training, affected the performance of fish ponds in the district, resulting in men hijacking the project to obtain benefits, leading to the collapse of the fish pond initiative. These factors contributed to the failure of fish pond projects in Lira District and Lango sub-region, in general. Although, fish ponds had a potential for generating income, other characteristics such as the high cost of construction and high operational costs, and difficulty in testing the project on a small-scale without incurring high costs, militated against their adoption by most farmers.

These findings corroborated the results of a research by Jagger and Pander (n.d), which concluded that the limited extent of Ugandan aquaculture indicates the need for education and technical training, and the integration of aquaculture into agricultural extension portfolios. The complex relationship between livestock and aquaculture systems provides an example of the degree of specialized knowledge that smallholder farmers require to effectively co-manage fish ponds and livestock that provide a source of manure for fertilizing ponds. In addition, the availability of suitable land, water, labour and inputs such as fish feed may also be primary production constraints. Jagger and Pander (n.d) also considered the critical importance of institutional stability, including access to credit and tenure security, and the development of post-harvest technologies and transportation systems that can support the delivery of fish products to markets.

3.5 Respondents Obtaining of Technical Service

Results show that extension services were relatively poor. While most farmers (79.8 per cent) did not get extension services, one-fifth (20.2 per cent) reported receiving technical support for the operation of their technologies. Most of those who reported getting extension services,

obtained services from government (48.3 per cent) and an equal percentage (48.3 per cent) got support from hired persons, while only 12.5 per cent got support from friends. While the government was found to be one of the main providers of extension services, technical assistance was increasingly being provided by the private sector. The motivator of this changing trend was found to be the profitability of agriculture, which reflected a gradual change from traditional agriculture to commercial agriculture, one of the major objectives of the agriculture policy. The farmers who obtained technical support found it useful in terms of use of knowledge for other productive activities (34.4 per cent). This was because the support was given as a package that did not only focus on technology use but extended to teaching farmers other agronomic practices. Through the support, farmers also learnt water storage technologies (15.6 per cent) and how to open water channels (12.5 per cent), which contributed to increased outputs (12.5 per cent). Other benefits from technical support included obtaining of seeds during demonstration (6.3 per cent), advanced knowledge in farming (6.3 per cent), especially seed multiplication, and increased incomes (6.3 per cent).

3.6 Constraints to the Use of Technologies

Findings revealed that of the 110 respondents who responded to this question, a quarter (25.5 per cent) indicated that lack of skilled labour was the main constraint affecting use of technology; followed by weeds, pests and diseases (20.9 per cent); financial resources constraints (19.1 per cent); natural hazards — floods, strong winds and storms (15.5 per cent); lack of better technology (8.2 per cent); seasonal dry spells (4.5 per cent); breakdown of equipment (4.5 per cent); reconstruction of the technology every season (0.9 per cent); and land conflicts and thieves (0.9 per cent). Analyses of constraints per water harvesting technology showed that the main constraints facing drip irrigation were weeds, pests and diseases, financial constraints, lack of labour, and technical support. The main constraints affecting furrow and ridge irrigation were lack of labour and technical support, weeds, pests and diseases, flooding during rainy seasons, strong winds and storms, financial constraints, lack of better technology and training; breakdown of equipment, and land conflicts and thieves. In the case of surface water tanks, the main constraints included limited financial capacity, lack of labour and technical support, breakdown of equipment, flooding during rainy seasons, strong winds and storms, and the need to reconstruct the tank every rainy season. The main problems affecting the use of underground water tanks were breakdown of equipment while the main constraints affecting fish ponds included lack of labour and technical support, weeds, pests and diseases, seasonal dry spells, and financial constraints.

While the main constraint facing drip irrigation were found to be weeds, pests and diseases the main constraints facing furrow and ridge irrigation were found to be lack of labour and technical support. Furthermore, while

the main constraint facing surface water tanks was lack of labour and technical support, the major constraints affecting use of underground water tanks was breakdown of equipment. The main constraints affecting fish ponds included lack of labour and technical support. The main constraint affecting all the water harvesting technologies was lack of labour and technical support. This result supports a research by Jagger and Pender (n.d) which found that aquaculture was relatively labour-intensive, indicating that regions with moderate or high population densities, relatively low wage rates and few off-farm labour opportunities would be best suited to its development.

Another study in Dodoma and other parts of Tanzania revealed that the water harvesting systems preferred and practised by farmers have not received enough technical support mainly because they operate outside the formal projects. This may be due to lack of regional policy and strategy geared towards the development of various systems for crop production (Hatibu and Mahoo n.d). While there was an abundance of unskilled labour, skilled labour was scarce in Lira District, with very few people trained in the management of water for production. The few skilled personnel were not able to provide training to the numerous farmers in the sub-region. Even where the available skilled personnel could train farmers in various techniques of water harvesting, farmers were neither able nor willing to pay for the training. Thus, they depended on the government or NGO support to provide training. Lack of skilled labour is a strategic issue as it also negatively impacted on the problems of weeds, pests and diseases, flooding, strong winds and storms, and choice and maintenance of technology. Addressing the issue of skilled labour would enable most of the constraints that affected technology use to be addressed. Indeed, households suggested technical support from the government, NGOs and other stakeholders, as ways of improving the use of technology.

As pointed out, for fish ponds, farmers depend on the government, NGOs or multilateral agencies such as FAO and WFP, or international donor organizations for technical and financial support. For example, a group of farmers in rural Lira District received support from FAO and WFP to construct and stock fish ponds. Another group obtained support from the US-based Africa Development Fund (ADF) for constructing and stocking a fish pond through a local intermediary NGO known as Development Training and Research Centre (DETREC). However, the fish pond project has since collapsed due to poor management.

Despite the existence of elaborate national policies guiding the use of water for production as stipulated in the Water, Agriculture and Fisheries policies, their implementation was found to be limited. Fifty six (56) per cent of households received technical support from hired individuals and friends combined, compared to 43.8 per cent, who reported getting support from the government. The technical support given to farmers was found to be linked to NAADS, NUSAF or a project initiated by NGOs. Extension

workers in the district hardly provide technical services to farmers in an individual capacity but do so in an official capacity. This was due to lack of financial resources and transport support to extension workers by the local government and extension government ministries who do not transfer adequate funds to the district to support agricultural production. On the demand side, farmers also hardly call extension workers to provide technical advice. This is due to the mentality that government extension workers should take the initiative in providing technical services as they have traditionally done, an attitude inconsistent with a shift in policy from traditional agriculture to commercial agriculture that requires farmers to take initiative.

While the water policy has the objective of developing technologies to harvest water from water bodies, to support non-rainfed agriculture, the implementation of this objective is only evident in the construction of valley dams and dams located in cattle corridor, which run from the southwest to northeast of Uganda. While the agriculture policy emphasizes the increase of the use of water for production in the areas of crop, livestock, fish and aquaculture, there is limited intervention to this effect. Similarly, while the fishery policy has the objective of supporting the development of aquaculture to bridge the gap between fish supply and demand, this has not been implemented. Most farmers have, therefore, depended on the support of agencies such as UN, FAO, WFP, NGOs, and private resources to acquire the technologies that tap water resources for production. The implementation of national policies that support the use of water for production has therefore been limited.

3.7 Suggestions to Improve Performance of Technology

Of the 98 persons who responded to this question, one-third (30.6 per cent) suggested technical support as a way of improving the technology (30.6 per cent), and about the same percentage (27.6 per cent) suggested that support from the government, NGOs and other stakeholders was welcome in order to improve the performance of water harvesting technologies. Suggestions related to ridge irrigation included expanding or enlarging the ridges and gardens (14.3 per cent) and creation of more ridges (3.1 per cent), de-silting of furrows to increase the flow of water that makes the ridges moist, and construction of more channels to increase the flow of water from the source to the furrows, to enable adequate amounts of water to reach crops planted on ridges. Suggestions for improvement of technologies, in general, included proper methods of farming (9.2 per cent), training (7.1 per cent), improved management of dams (3.1 per cent), afforestation (2 per cent), provision of alternative water sources during the dry season (1 per cent) and permission to use wetlands (1 per cent).

District production officials suggested the improvement of extension services by providing adequate funds to support the work of production staff. The district production staff (agriculture, fisheries and forestry) were not provided with transport and adequate money to perform their work.

Hence, they were unable to provide technical service to farmers in need. In addition, farmers should be provided with tools to enable them effectively use water for production of crops and horticulture. Furthermore, they should be assisted in identifying seeds that grow well in particular soils. According to the district fisheries officer, farmers who were not assisted had a tendency to put tilapia in fish ponds despite the fact that tilapia does not grow well in fish ponds. After three months, the tilapia start reproducing, hence most of the food goes towards reproduction rather than building their bodies. When many fries are produced, they become stunted. For tilapia to do well in fish ponds, a mono-sex approach is best, where only males or only females should be put in fish ponds. However, where both males and females are put in fish ponds, hormones should be used to sterilize all the males, hence prevent reproduction. Similarly, some farmers who believed that any seed would grow in any soil had a tendency to grow fruit trees in unsuitable soils, leading to stunted growth and poor yields. Therefore, regardless of the availability of water for production, lack of proper seed selection may contribute to poor yields.

3.8 Water Use and Improvement of Living Conditions

Virtually all respondents reported that the production of crops arising from water harvested had improved their living conditions. For a majority, improved living conditions were by provision of basic needs in terms of food items (62.6 per cent) followed by generation of income (32.9 per cent) and for 4.5 per cent of respondents, the money was used for paying school fees. Most farming households produced crops such as maize and beans both for consumption and sale; some commodities such as rice, fruits (mainly oranges and mangoes) and vegetables were produced for sale. Extension workers also confirmed that the growing of vegetables using furrow and ridge irrigation brought some good income to farmers. This was because these were usually grown during dry seasons when agricultural produce was in short supply, hence increasing their demand. On the other hand, the construction of fish ponds had not improved the quality of life of households because of collapse of fish production due to failure to maintain the cycle of production by not reinvesting the money obtained to restock fish.

3.9 Suggestions for Better Water Use

Most respondents suggested provision of technical support (40.3 per cent) for better water use. Other suggestions included improved water management and storage (14.3 per cent) renovation and proper maintenance of dam by the government to retain more water (10.4 per cent), training (9.7 per cent), creating, clearing or expanding ridges and channels (8.4 per cent), financial support by government through NAADS (8.4 per cent), exposure to better alternatives (7.1 per cent) and permission to use wetlands (1.2 per cent).

The district technical officers highlighted constraints to use of water as drying of water from wetlands during dry seasons, difficulty in transporting water from the source to the gardens, lack of means to use full irrigatio, and lack of skills to tap the water for use. Suggestions to deal with these constraints included providing transport and money to allow extension staff to deliver technical service to farmers, and provision of grants or subsidized loans to farmers, to purchase the equipment needed to tap water for production of crops, fruits, livestock, and fish.

3.10 Implementation of Water for Production Policy

In Uganda, the implementation of water for production policy targets certain areas that are arid and semi-arid such as Karamoja region in Northeastern Uganda and Nakasongola within the cattle corridor, in north-central Uganda. While in Karamoja, the government has constructed dams to provide water for livestock, in Nakasongola, valley tanks have also been constructed to provide water for livestock. These dams and valley tanks were poorly constructed, and because they were non-functional, failed to serve their purpose. In Kole District in Lango sub-region in Northern Uganda, the Leye dam was built by the government to serve as a water reservoir for livestock and fish. However, it resulted in the displacement of a large population, and loss of land and property, yet no compensation was provided to the people. Communities have, therefore, tended to be suspicious of government intentions when water harvesting projects are being implemented.

In the district of study, government policy that promotes the use of water for production has been implemented by construction of fish ponds by government agencies such as NAADS and NUSAF. In regard to crop production, the government supported the development of Olweny Irrigation Scheme on Olweny River, to enable farmers produce rice. The project was initially successful as many farmers close to the project site grew paddy rice and increased their income, and enhanced food security. Unfortunately, however, the project was not sustained due to lack of funding to enable the irrigation system continue functioning, which led to the collapse of the project. In the 1960s, the government built many dams in the Lango sub-region, including the study district, some of which include Igar, Amwoma and Aloï dams, to provide water for livestock production, fruit growing and fish production. These dams have not been rehabilitated and are therefore in a sorry state. No dams have been built in recent times in the sub-region.

In March 2012, a conference was held at State House on Poverty Reduction and Enterprise Selection chaired by the president. The target was that every household in Uganda should achieve 20 million Uganda shillings (US \$ 8,000) per annum. Strategies of achieving this, relevant to the study area, would involve revival of irrigation schemes in Olweny, Aloï Ongom, Atera and Atura ranches. At the end of the conference, a directive was given to

the Ministry of Agriculture to implement these strategies. However, it is yet to be implemented.

Based on the preceding discussions, key constraints to the implementation of water for production policy in Uganda include the initiation of projects for political reasons, to reward certain people or attract their support, even when the projects are not feasible. In a related manner, projects are announced by politicians to attain political objectives, without feasibility studies. The third factor is the resistance of communities to innovations, including water for production, due to lack of involvement of the communities in these innovations at inception, hence they do not understand project objectives and fail to accept them.

The study established that the implementation of water for production policy was poor. Suggestions for improvement of policy implementation included involving the farmers in the design of water harvesting projects, to promote acceptability and sustainability of water for production projects; improvement of extension services and provision of agricultural training to enable farmers to improve their agricultural enterprises; and improving road networks to give farmers better access to markets, and boost household food security and incomes.

3. Conclusions

Male respondents were the dominant heads of households, forming about six in ten respondents, compared to females who were nearly four in ten respondents. About four in ten of the respondents were relatively young (26-35 years) and most were full-time farmers (65.3 per cent), one-fifth were traders practising farming and only 5.7 per cent were civil servants, being the category of respondents who have the financial capacity to invest in fish ponds and drip irrigation while the majority of farmers were engaged in furrow and ridge irrigation that did not require heavy investment. Two-thirds of respondents had attained primary education one-fifth had attained secondary education and one-tenth obtained vocational training reflecting the need for technical education to facilitate successful use of water harvesting technologies.

Furrow and ridge irrigation was the most used water harvesting technology, as indicated by 7 in 10 respondents. Slightly less than 10 per cent used drip irrigation and surface water tanks, while a negligible percentage (2.9 per cent) used fish ponds and underground water tanks (1.7 per cent). All the ponds were maintained through the farmer's own resources except group fish ponds that were supported by UN, WFP, FAO, and NUSAF. The main uses of water comprised growing of crops, rearing of livestock, and to some extent, fish production.

The main drivers for adoption of water harvesting technologies included farmers' experience of the technology through trial, observation, and perception of the characteristics of the technology (complexity, cost and

benefits), and to some extent, potential for income. Institutional and social factors did not have significant influence on farmers' decision to adopt the technology. Technologies that farmers had experienced through trial, such as furrow and ridge irrigation, were more likely to be adopted as well as technologies that farmers perceived to be of low cost such as furrow and ridge irrigation, and surface water tanks. These results tallied with the report by Raffler and Naugle (n.d), which showed that new technologies are only useful to the extent that they are affordable and acceptable to the intended beneficiaries. This led to the conclusion that just as few of the projects have succeeded in combining technical efficiency with low cost and acceptability to local farmers or agro-pastoralists, partly due to lack of technical know-how, and often due to the selection of inappropriate approaches, with regard to prevailing socioeconomic conditions (Critchley and Reij 1989).

Furthermore, technologies that were perceived to generate income such as furrow and ridge irrigation, and drip irrigation, had more chances of being adopted. In addition, the level of complexity of the technology also either facilitated or constrained ease of adoption and operation of the technology. Technologies perceived to be simple to use, such as furrow and ridge irrigation, were more likely to be adopted than more complex technologies such as drip irrigation and underground tanks. The more the technology was perceived to have a positive impact (enhancing income generation), such as furrow and ridge irrigation, the more likely that it would be adopted. This is consistent with findings of a research by Drechsel et. al (n.d), which revealed that adoption of water harvesting and conservation technology was a function of the characteristics of the technology proposed and farmers' perception of advantages.

The drivers were found to counteract each other's influence on farmers' decisions. While experience of the technology motivated a farmer to adopt a technology like drip irrigation, the high cost of establishing the technology and high operational costs discouraged its use. Similarly, while perception of benefits (income generation) from a technology such as fish ponds encouraged a farmer to adopt it, the high cost of construction and operation constrained adoption. Institutional and social factors did not have any significant influence on the decision of farmers to use the technologies.

Farmers' experience of the technology was the main factor that influenced farmers' decision to use the five water harvesting technologies, with the highest influence linked to furrow and ridge irrigation. Adoption of drip irrigation was low because of difficulty of adoption and high operating costs, which made it the most expensive technology, with requiring about Uganda shillings 3,406,923. In comparison, furrow and ridge irrigation cost only one-tenth (Uganda shillings 311,291) of the amount required by drip irrigation. The use of drip irrigation was only possible for a few farmers who had the financial resources to adopt and operate the technology.

Farmers experience had the highest influence (64.5 per cent) on furrow and ridge irrigation, making it easy to adopt, followed by simplicity of operation (28.9 per cent). Potential for income (4.94 per cent) was not a strong driver for adoption of furrow and ridge technology. This result confirmed the findings of a research by Hatibu and Mahoo (n.d), which revealed that the potential for increasing cash income was a big factor influencing the adoption of rainwater harvesting in Dodoma. Where clear benefits have been demonstrated, farmers have been ready to undertake, on their own initiative, huge capital investment in rainwater harvesting, for instance, purchasing tractors to attain deep tillage and construction of bunds for paddy rice production. Furrow and ridge irrigation required physical labour to construct and operate the technology, but did not require a fuel engine or electric power and was low cost, hence affordable by nearly all farming households. For one-third of the respondents, its simplicity was appealing. Since it did not require elaborate technical service, it could be used by farmers who were not highly educated and those without access to extension services (only one-fifth had access to extension service), explaining why respondents in the current research, most of whom had only attained primary education, were able to adopt and use furrow and ridge irrigation.

Of the few respondents who reported using surface water tanks, most were driven by the experience of the technology, in contrast to 7.14 per cent, who were driven by ease of use, and another 7.14 per cent, who used surface water tanks because they were perceived to be without institutional and social constraints. Compared to furrow and ridge irrigation, adoption of surface water tanks in the research district was low. Although some farmers adopted surface water tanks due to the experience of the technology, the perception of the simplicity of the technology and institutional and social factors did not have any significant influence on the decisions of respondents to adopt the technology. Potential for income did not have any influence on adoption of the technology. The low adoption of drip irrigation tallied with the results of a study by Hatiboo and Mahoo (n.d), which showed that despite the demonstrated benefits of tapping rainwater in Dodoma, few individuals or villagers have constructed their own reservoirs.

Of the tiny percentage of respondents (1.7 per cent) who reported using underground water tanks, more than two-thirds were driven to adopt the technology because of the experience of the technology, compared to more than one-third who were driven by a perceived ease of operation. The low adoption of underground water tanks was due to high construction costs and lack of potential for income generation. Institutional and social factors did not have any influence on adoption and use of underground water technology.

Of the few respondents (2.9 per cent) who adopted fish ponds, two-thirds were influenced by the perception that it was less complex and less costly

to operate, compared to 4 in 10 who were driven by experience of the technology. Overall, the low adoption of fish pond technology was due to high construction and operational costs, only affordable by a few people with personal resources and groups funded by development organizations and government development programmes. Fish ponds had the second-highest average cost of Uganda shillings 920,000, compared to other technologies. Potential for income, and institutional and social factors had no influence on adoption of fish ponds. These conclusions corroborated the research by Jagger and Pander (n.d), which revealed that the limited extent of Ugandan aquaculture indicates the need for education and technical training as well as availability of inputs, such as water, labour fish feeds, credit, and a good transportation system.

The research established that extension services were poor, evidenced by 8 in 10 respondents not accessing extension services, and only one-fifth receiving technical support for their technologies. The sources of most extension services were government (48.3 per cent) and hired people (48.3 per cent), while only 12.5 per cent received extension services from friends. While government was still the main provider of extension services, the private sector was increasingly providing extension services to farmers. The motivator of this changing trend was the profitability of agriculture, which reflected a gradual change from traditional agriculture to commercial agriculture, one of the major objectives of the agriculture policy.

The main constraints affecting all the water harvesting technologies were lack of labour and technical support. This supports a research by Jagger and Pender (n.d), which found that aquaculture was relatively labour intense, indicating that regions with moderate or high population densities, relatively low wage rates and few off-farm labour opportunities, would be best suited to its development. Another study in Dodoma and other parts of Tanzania revealed that the water harvesting systems preferred and practised by farmers had not received adequate technical support, mainly because they operate outside formal projects. This may be due to lack of regional policy and strategy geared towards the development of various systems for crop production (Hatibu and Mahoo n.d). While there was an abundance of unskilled labour, skilled labour was scarce in Lira District, due to a very limited number of people trained in the management of water, for production. The few skilled individuals were unable to provide training to the numerous farmers in the sub-region. Even where skilled individuals could train farmers in various techniques of water harvesting, the farmers were neither able nor willing to pay for such training. They, therefore, depended on government or support from NGOs to provide training. Lack of skilled labour is a strategic issue as it also negatively impacted on the problems of weeds, pests and diseases; flooding; strong winds; storms; and choice and maintenance of technology. Addressing the issue of skilled labour would effectively tackle most of the constraints that affected technology use. Indeed, households suggested technical support from the

government, NGOs and other stakeholders as a way of improving adoption of water harvesting technologies.

Despite the existence of elaborate national policies guiding the use of water for production stipulated in the water, agriculture and fisheries policies, their implementation was found to be limited. While the water policy has the objective of developing technologies to harvest water from water bodies, to support non-rainfed agriculture, the implementation of this objective was only evident in the construction of valley dams and dams located in the cattle corridor. While the agriculture policy emphasizes the increase in the use of water for production in the areas of crop, livestock, fish and aquaculture, there was limited intervention to this effect. Similarly, while the fisheries policy has the objective of supporting the development of aquaculture to bridge the gap between fish supply and demand, this has not been implemented. Most farmers have, therefore, depended on the support of other agencies such as UN, FAO, WFP, and NGOs as well as private resources, to acquire technologies that tap water resources for production.

Virtually all respondents reported that the production of crops arising from water harvested had improved their living conditions by provision of basic needs (62.6 per cent), generation of income (32.9 per cent) and paying of school fees (4.5 per cent). Most farming households produced crops such as maize and beans both for consumption and income; some commodities such as rice, fruits (mainly oranges and mangoes) and vegetables were produced for income. These were usually grown during the dry season when agricultural produce was in short supply, increasing the demand. On the other hand, the construction of fish ponds had not improved the quality of life of households because failure to reinvest the money obtained from the enterprise, to restock fish, led to the collapse of the project

Four in ten respondents suggested provision of technical support for better water use. Other suggestions included improved water management and storage (14.3 per cent), renovation, and proper maintenance of dam by the government to retain more water (10.4 per cent), training (9.7 per cent), creating, clearing or expanding ridges and channels (8.4 per cent), financial support from the government through NAADS (8.4 per cent), and exposure to better alternatives (7.1 per cent).

The study established that the implementation of water for production policies was poor. Suggestions for improvement of policy implementation included involving the farmers in the design of water harvesting projects, to promote acceptability and sustainability of water for production projects; improvement of extension services and provision of agricultural training to enable farmers to improve their agricultural enterprises; and improving road networks that would increase access of farmers to markets and boost household food security and incomes.

Innovative water harvesting methods that have been successfully adopted and used by farmers, such as furrow and ridge irrigation, low cost drip irrigation using recycled water bottles, and surface tanks, should be disseminated to other farmers in the district, and the country as a whole. Farmers should be financially and technically supported to adopt and use fish ponds due to the high adoption and operational costs as well as technical know-how that are involved.

References

- Brin, P., Kayoby, G. and Nagoti, N. (2002) Soil management in Teso and Lango. NARO/DFID Client Oriented Agricultural Research and Dissemination Research Project. Unpublished report.
- Critchley, W. R. S. and Reij, C. (1989) Water harvesting for plant production. Part 2: Case studies and conclusions from Sub-Saharan Africa. Retrieved March 18, 2012, from www.aletta.nu/indigenous
- Dai, R. 2005. Low cost rainwater harvesting. Retrieved March 27, 2012, from www.cd3wd.com/cd3wd_40/UWWKDTU/WP55/PDF/wp55.pdf
- Drechsel, P., Olaleye, A., Adeoti, A., Thiombiano, L., Barry, B. and Vohland, K., (n.d) Adoption driver and constraints of resource conservation technologies in Sub-Saharan Africa. International Water Management Institute (IWMI) West Africa Office, Accra. Retrieved February 3, 2012, from westafrica.iwmi-org/Data/Sites/17/Adoptionconstraints-Overview-pdf.
- Evanari, M., Shanan, L. and Tadmor, N. H. 1971. The challenge of a desert. MA: Harvard University Press.
- Hatibu, N. and Mahoo, H. (n.d) Rainwater harvesting technologies for agricultural production: A case of Dodoma, Tanzania, Sokoine University of Agriculture. Retrieved March 15, 2012, from www.animaltraction.net/contil/contil-hatibu-water_harvesting-TZ.pdf.
- FAO (2005) Water Report No. 29. *FAO Information System on Water and Agriculture*. Rome. Jagger Pamela and Pender John (n.d) Potentials and constraints for aquaculture in Sub-Saharan Africa: The case of Uganda. Retrieved February 6, 2013, from oregonstate.edu/dept/iifet/2000/abstracts/jagger.html.
- Finance, Planning and Economic Development (MFPED), Republic of Uganda. 2000. Plan for the modernization of agriculture: Eradicating poverty in Uganda: Government strategy and operational framework. Kampala: MAAIUF and MFPED.
- Ministry of Water, Lands and Environment (MWLE), Republic of Uganda. 1999. *A National Water Policy*. Kampala: MWLE.
- Pacey, A. and Cullis, A. 1986. Rainwater harvesting. The collection of rainwater and runoff in rural areas. London: Intermediate Technology Publication.

- Tayebwa, B. 2008. A case study on fish farming in Uganda. Uganda Cooperative Alliance. Unpublished report.
- Uganda National Wetlands Programme (UNWP) and IUCN. 1998. The present economic value of Nakivubo Urban Wetlands. Kampala.
- Uganda Water and Sanitation NGO Network (UWASNET) 2001. A summary of key legislation and policies on water and sanitation in Uganda. Retrieved February 6, 2013, from www.uwasnet.org
- Raffler, P. and Naugle, J. (n.d) Demand for rainwater harvesting devices in Uganda. Retrieved February 6, 2013, from faculty.som.yale.edu/mushfiqmobarak/Uganda.htm.
- Zaunderer, J. and Hutchinson, C. F. 1988. A review of water harvesting techniques of the arid Southwestern US and North Mexico (draft). Working Paper for the World Bank's Sub-Saharan Water Harvesting Study.

The Role of Local Institutions in Water Use Management and its Implications for Poverty Reduction: The Case of Small-Scale Irrigation in Tigray

Fredu Nega and Sintayoh Fisseha

Abstract: The overall goal of this paper is to understand the role of local water use institutions in water use management and community relations, and its implication on poverty reduction in Tigray region of Northern Ethiopia. Based on 289 households in three irrigation schemes, the paper measured the operation of Water User Associations (WUA) and analyzed the implications on poverty, the former being proxied by levels of participation of farmers in cleaning and maintenance of irrigation canals. The study findings indicate significant differences in water use efficiency and productivity that is attributable to differences in the strength and functionality of the local institutions. However, there was no direct impact of WUA on poverty, the latter being mainly influenced by household characteristics and ownership of productive assets. Furthermore, study results indicate that farmers' knowledge about the rules and regulations of WUA enhances their engagement in collective action such as cleaning and maintenance of irrigation canals.

Keywords: Water use Institutions, Poverty Reduction, Water use Management, Small-scale Irrigation.

1. Introduction

1.1 Background

In many drought-prone countries, including Ethiopia, there has been an optimistic view regarding irrigation development as a strategy to sustain agricultural production and ensure food security. In these countries, the key constraint on further increase in agricultural production is the scarcity of water. Therefore, national planners are strongly attracted to irrigation as a means of supporting future food strategies.

In line with this, the government of the Federal Democratic Republic of Ethiopia (FDRE) has considered irrigation as a vital strategy in ensuring food security. More emphasis has been directed to irrigation in subsequent strategies devised by the government. The National Food Security Strategy, adopted in 1996 and 2002, envisaged implementation of cost-effective irrigation schemes in drought-prone and densely populated areas (FDRE 1996; FDRE 2002). The Ethiopian Interim Poverty Reduction Strategy Paper (2000/01-2002/03) emphasized the need for agricultural growth and irrigation development in order to reduce the level of poverty and improve food security in the country. As a follow-up of the poverty reduction strategy papers, the ambitious Growth and Transformation Plan (GTP) puts

expansion of irrigation high on the agenda, and for subsequent years, it is considered the main engine for poverty reduction.

The plan is to increase agricultural production by 129 percent over the next five-year period, a significant portion of which could be achieved through expansion of irrigation. The government of Ethiopia's policy target is to ultimately reach five million hectares under irrigation at the end of the second GTP, by 2020 (FDRE 2010).

Tigray is one of the regional states of Ethiopia implementing the country development strategies, Agricultural Development Lead Industrialization (ADLI). The ADLI strategy in the region is based on resource conservation. Accordingly, the main emphasis is given to water as the region has limited water resources. This has motivated the regional government to build all possible water harvesting mechanisms such as ponds, small-scale dams, river diversions, and hand-dug wells. To this end, the regional government and the local community have built 79 micro-dams (Tsehaye et al. 2007).

Nonetheless, in water resource development, harmonization of the different demands for both upstream and downstream users, and consideration of the rights of existing users of water from dams is essential in the determination of irrigation priority rights. However, this issue had not been addressed in Tigray. Local communities resolve the matter through their community norms and practices. In line with this, a number of institutions — informal, cultural as well as formal institutions — are involved and have opted to deal not just with resource issues but also water allocation problems. One important consequence of frequent water conflicts has been the adaptation of local water use associations, locally termed as *abo mai* (Fredu et al. 2006).

As vehicles of policy change and implementation, institutions are the filters which determine the success (or failure) of livelihood strategies. Both formal and informal institutions are important, particularly at the community and district level. Institutions can determine the capacity of households to increase their asset base and secure new sources of income. The general mediating role of institutions — between people and the environment, between individuals and collectivities, and between different collectivities — makes them essential in improving resource management, increasing productivity and reducing poverty of small-scale farmers.

The involvement of local institutions in water resource management and decision-making delivers direct benefits to recipients at community and household level and indirect benefits at system level. For the beneficiaries, these benefits accrue in terms of increasing productivity, profitability, labour-saving due to high water use efficiency, improved maintenance, and accountability. These effects may translate into system-wide benefits, thereby improving the overall performance of irrigation systems and promoting sustainability of these systems (Hussain and Hanjra 2004). This helps to explain why the irrigated water resource management approach has

been greatly emphasized in recent years and why it is becoming the main focus area for governments, nongovernmental organizations, scholars, and civic societies.

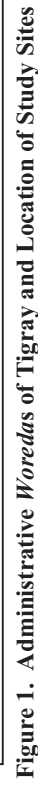
However, there is little evidence on how local institutions function in resource management in Ethiopia, and even much less when it comes to irrigation water utilization. Irrigation development in Ethiopia has been focused on the agronomic, engineering and technical aspects of water projects, with little consideration to issues of management, beneficiary participation and availability of institutional support services, despite the fact that the success of irrigation systems is highly influenced by policy, institutional and social factors much more than technical issues (Gebemedhin and Peden 2002).

The need to identify factors that facilitate or hinder the development and effectiveness of both formal and informal local institutions and organizations is important (Gebemedhin et al. 2002) as this is a topic where minimal research has been conducted. Therefore, this research focuses on the role of institutions in water use management and community relations, and implications for poverty reduction in the northern part of Ethiopia (Tigray). It helps to address the dearth of knowledge about the importance of local institutions in water use management. The research investigates the role of institutions in water use management and explores ways of improving efficiency in water use. It further investigates if the role of local water use institutions contributes to poverty reduction, through enhancing productivity, and hence boosting the income, of rural households.

2. Methodology and Data Sources

2.1 Study Area

The study was conducted in Tigray regional state in the northern part of Ethiopia. Tigray covers an area of approximately 54,572 square kilometres. It has a total population of 4,314,456, out of which females comprise 49.2 percent and males 50.8 percent. About 80.5 percent of the population lives in rural areas while the remaining 19.5 percent are urban residents (CSA 2007). The altitude of the region varies from about 500 meters above sea level (masl) in the northeast to almost 4,000 masl in the southwest. The agro-ecology of the region is broadly categorized into lowland (Kola — less than 150 masl), medium highland (Weinadega — 1,500 to 2,300 masl), and upper highland (Dega — 2,300 to 3,000 masl). About 53 percent of the region is lowland, 39 percent medium highland, and 8 percent upper highland (BoPED 1995).



Source: Courtesy of UNDP-Emergency Unit for Ethiopia (EUE), 1996

Figure 1 shows the study areas. Four *tabias*,² namely Adisalem, Amdiweyane, Rubafeleg and Meremete were selected for the study. Rubafeleg is located in Atsibi Wonberta *woreda*,³ Meremete in Enderta *woreda* and the remaining two *tabias* (Adisalem and Amdiweyane) in Seharti Samre.

The study *woredas* were selected purposely. All these *woredas* have irrigation schemes, mainly from micro-dams, constructed in 1997 (1989 E.C⁴), 1993 (1985 E.C) and 1994 (1986 E.C), respectively, and all are managed by WUAs. All these schemes are managed by WUAs but have different water use and management systems.

2.1.1. Description of Irrigation Schemes

Three irrigation schemes, namely Haiba, Hizaeti Wedicheber and Rubafeleg in the four *tabias* identified above were selected for the study. The following is a description of the dams.

Haiba

Haiba is the main source of water for irrigation for the two *tabias* (Adisalem and Amdiweyane) in the study area. Constructed in 1997/98, the dam is located in the south-eastern zone of Tigray, Seharti-Samre *woreda* at *Figna* village (Amdiweyane Debrehaila *tabia*) at an altitude of 2,263 masl. The dam is situated in the Haiba plane, which often experiences drought and ill distributed rainfall, resulting in food insecurity.

The total catchment area that drains into Haiba dam is 26 km² with a mean annual rainfall of 642 millimetres. With a crest length of 404 metres, height of 16 metres and surface area of 45.41 hectares, the dam has a water-holding capacity of 3.1 Mm³ (Tsehaye et al. 2007) but due to siltation the current capacity is reduced to 2.85 Mm³.

Although there is no measured sediment data as to how much sediment is transported every year to the dam from the upper watershed, it can be observed that the dam is being filled by sediment. According to estimates by local professionals (development agents), the sediment transportation is estimated to be in the range of 800 to 1000 m³/km²/year. Thus, by considering the catchment characteristics of the area, the sediment inflow rate is taken to be 1000m³/km²/year (Tigray Bureau of Water Resources, Mining and Energy (TBoWRME) 2010, cited in Tekleyohannes 2011).

Hizaeti Wedicheber

Hizaeti Wedicheber, which serves as the main source of water for irrigation to communities in Meremete, is located in the southern zone of Tigray, in Enderta *woreda*, at an altitude of 2,245 masl. The area receives a mean annual rainfall of 611 millimetres. The dam has a height of 14.5 metres, crest length of 5,098 metres, surface area of 32.57 hectares and water-holding capacity of 1.24 Mm³. The total area of the catchment that drains to

the dam is 33 km², with a drainage density of 1.9 km/km² (Tsehaye et al. 2007).

The dam was constructed in 1996/97 by the Bureau of Agriculture and Natural Resources of Tigray region for irrigation and livestock drinking purposes. It was designed to irrigate 80 hectares but currently irrigates 50 hectares

Rubafeleg

Rubafeleg is located in the eastern zone of Tigray, in Atsbi Wenberta *woreda*, at an altitude of 2,747 masl. It is the main source of water for irrigation to communities in Rubafeleg *tabia*. The dam was constructed in 1995/96. It has a height of 17.5 metres, dam crest length of 415 metres, original water-holding capacity of 900,000 cubic metres and a maximum depth of 11 metres. The total catchment area that drains into the dam is 25.2 km² with a drainage capacity of 1.45 km/km² (Tsehaye et al. 2007). The dam's designed irrigation capacity was 80 hectares but it is currently irrigating lower than the capacity.

2.2. Data and Methodology

2.2.1. Data Sources

The data for this study was based on fieldwork in four *tabias* from three *woredas* in Tigray region of northern Ethiopia. A two-stage sampling technique was employed. The primary sampling units (PSUs) were *tabias*. Sample *tabias* were selected on the basis of secondary information collected from all *woredas*. *Tabias* with irrigation schemes were identified and from this list, four *tabias* were purposively selected — Adisalem, Amdiweyane, Meremiete and Rubafeleg. The three irrigation schemes in these four *tabias* were established at different times and are all administered by WUAs. Moreover, based on the secondary information collected from respective *tabias*, significant differences were noted in the strength and functionality of the WUAs, which was useful for comparison purposes.

In the second stage, a total of 310 sample households were selected from the four *tabias*. Sample households were distributed proportionately in each *tabia*. Simple random sampling was used to select sample households from each *tabia*. List of households who use irrigation was obtained from each *tabia* and sample households were selected at regular intervals with a random start.

A multipurpose questionnaire was used to gather information on household income, expenditure, household assets, access to dam water, technology use, and water management practices as well as relevant agricultural production, socioeconomic, gender relations, and livelihood indicators. The survey questionnaire was administered to the 310 sample households selected from the four *tabias*.

Besides household-level information, village-level information was collected through key informant interviews. A short questionnaire was developed and was presented to key informants identified (mainly from the water committee) from each *tabia*, to obtain information on irrigation water use and management systems of the irrigation schemes.

Ten experienced enumerators who had previously served in similar surveys were hired for data collection. The enumerators underwent an intensive two-day training session. Pilot testing was performed. Close and regular supervision occurred during the fieldwork. Completed questionnaires were checked on the spot and those with significant inconsistencies had to be filled again by informants.

Data processing was done after fieldwork. All forms were manually checked to ensure that they had been completed properly and coding was done. Once coding was completed, data encoders were hired for data entry. Data was processed using STATA software and appropriate econometric techniques were used to analyze data in each of the chapters that follow.

2.2.2. *Quantitative Method: Local Institutions, Water Use Management, Income and Poverty*

Using the information collected from the 310 sample households, the relationship between functionality of local institutions, water use management, income and poverty was explored. First, local institutions that govern the use of water for irrigation were identified. The operations of these institutions was assessed in terms of indicators of presence of collective action.

The effectiveness of the operations of local WUAs measured in terms of the above indicator is expected to influence the water use management system, which in turn will influence the level of productivity and hence the income and poverty levels of the local irrigation users. These relationships were explored using multivariate regression analysis as indicated below.

a) **Local institutions and water use**

The link between water use per hectare and its determinants can be represented by the following equation:

$$W_{jk} = \beta_1 M_k + \alpha_j Z_{jk} + \gamma_j D_{jk} + \epsilon_{jk} \text{ ----- (1)}$$

where W_{jk} represents average water use per hectare for household j in village k . The rest of the variables explain water use. M_k is a measure of the operation of local level institutions in village k , measured in terms of indicators of presence of collective action; Z_{jk} is a matrix of control variables and represents other village and household factors that affect water use. Specifically, we include a number of variables to hold constant the nature of the village's production environment such as the level of irrigation investment per hectare, household characteristics such as age, education of the household head, and land endowment. Finally, the model

also includes, the D_{jk} village dummy. The β_i , α_j and γ_j symbols, are parameters to be estimated while ϵ_{ijk} is the error term that is assumed to be uncorrelated with other explanatory variables in the initial equation.

b) Water management, production, income and poverty

Even though a common conclusion regarding the role of local institutions in irrigation water and resource management is lacking as explained by different scholars, their operations, when efficient, at least leads to better management of water use. In this section, the effectiveness of the operations of local level institutions and how this affects agricultural production is measured. The impact on income and incidence of poverty is then examined. In addition to water management, other socioeconomic factors influence agricultural production and play a role in determining income and poverty levels. In order to ascertain whether the effectiveness of the operations of local level institutions affects outcomes, it is necessary to control these other factors. To achieve this, the multivariate model is specified for each of the three outcomes.

i) Local institutions and agricultural production

The link between agricultural production and its determinants are:

$$Q_{ijk} = \beta_i W_{ijk} + \delta_i X_{ijk} + \gamma_i D_{ijk} + \epsilon_{ijk} \quad \text{-----} \quad (2)$$

where Q_{ijk} represents the yields of selected types of crops grown through irrigation from the i th plot of household j in village k ; W_{ijk} measures water use per *timad*; X_{ijk} measures other inputs in the production process, which include labour input per *timad* measured in labour man days, D_{ijk} fertilizer per *timad* and other expenditure such as pesticides per *timad*; and D_{ijk} measures village dummy. The impact of effectiveness of operation of local level institutions is measured through water use variable.

ii) Local institutions and income

The following equation is used to examine the relationship between income and other factors:

$$Y_{jk} = \beta_i M_{ijk} + \alpha_j Z_{ijk} + \gamma_j D_{jk} + \epsilon_{jk} \quad \text{-----} \quad (3)$$

where Y_{jk} represents irrigation cropping income per capita for household j , while the other variables are the same as in equation 1 above.

iii) Local institutions and poverty

In a similar manner, the effects of the operations of local institutions on poverty was examined. Expenditure approach was used to measure poverty. A national poverty line was used to identify the poor and the non-poor. To establish the relationship between poverty and its determinants, the following regression equation is used:

$$P_{jk} = \alpha + \beta M_k + \delta Z_{jk} + D_{jk} + \epsilon_{jk} \text{ ----- (4)}$$

where P_{jk} represents poverty status as poor (under the poverty line) or not.

3. Management Systems in Collective Irrigation Management

Irrigation institutions are defined as the collective arrangements at irrigation scheme level for water control and use, which include water distribution, construction of infrastructure, maintenance, and rehabilitation. Key research issues regarding collective action for irrigation management include the manner in which people organize themselves with respect to irrigation water, identifying consistent and detectable influences of policies and other instruments that can be deployed to modify stakeholder behaviour, and determining how extension and common property management can be used to facilitate the role of local organization in water management.

In this section, the WUA in the three irrigation schemes is examined as well as determinants of collective action.

3.1 Water User Associations (WUA)

In most developing countries, irrigation development projects and their operations and management (O&M) are executed by the government. Recently, transfer of O&M responsibility and irrigation schemes from the state to Water User Organizations (WUOs) became necessary due to the failure of the public sector in financing or recovering water fees from farmers. The transfer was also necessitated by the government's desire to reduce costs, reallocate income and boost investment in irrigation and drainage systems.

The aim of establishing WUA is to develop the participatory irrigation management concept for increasing water use efficiency, through the involvement of all stakeholders, as much as possible, in the various management activities. A water user association is a group of farmers, all served by a common source of water, who come together to allocate, distribute, and manage water. WUA allow farmers to perform activities that are more difficult or impossible to accomplish individually.

The creation of WUA is justified by the participatory approach in water management, which allows farmers to concentrate their efforts and

resources in joint actions, aimed at the optimum utilization of water resources on irrigated lands.

WUA are empowered to act on behalf of their members in their relations with local water management districts and local administrative entities, to solve problems of water supply, to conclude contracts for construction and repair, and to maintain irrigation schemes and facilities, as well as other contracts and transactions allowed by existing legislations.

In light of the above justifications, water resources in the irrigation schemes in Tigray, including the three irrigation schemes in the study areas, are managed by WUA. Under normal circumstances, everybody who is a beneficiary of irrigation water is a member of WUA in a particular scheme. The WUA has its own rules, methods and sanctions for selecting the executive committee, raising finances, settling disputes among irrigation water beneficiaries, and supervising provision of the irrigation water service.

The general assembly of the WUA elects the executive committee, which is often referred to as the Water Users Committee (WUC). The following table shows the number of committees in each of the three irrigation schemes in the study areas.

Table 1. Number of members of Water Users Committee

Irrigation scheme name	Number of WUC
Haiba	10
Hizaeti Wedicheber	11
Rubafeleg	8

SOURCE: Authors' survey data

The WUC, which often includes chairperson, vice-chairperson, auditor, treasurer, secretary, and other members, is the executive body for managing and utilizing water use and other issues on the irrigation scheme as well as the official link between the WUA, government and other institutions associated with the irrigation scheme.

WUAs have by-laws explicitly meant to administer water resources from the irrigation schemes. These rules and regulations are often drafted by the Office of Agriculture and Natural Resources and discussed by members of WUA. Collection of fees from users, and fair and equitable distribution of water are just two of the many roles and responsibilities entrusted to the WUC.

Fees paid by users and water distribution systems differ from one irrigation scheme to the next. For example, in the three irrigation schemes, contributions range from 12 birr per user in Haiba to 60 birr per quarter of a hectare of land irrigated in Hizaeti Wedicheber. Similarly, distribution of water is different in the three irrigation schemes. In Haiba, irrigation users are grouped into smaller groups and a lottery method is used to assign which group should irrigate and when. In Hizaeti Wedicheber, similar grouping is followed but distribution is made on a consensus basis. Representatives of the smaller groups often discuss with the water committee and set out a schedule on a consensus basis. In Rubafeleg, the committee collects suggestions from the users regarding who should get water first — whether to begin with the farmers at the far end of the dam or those close to the dam. Once schedules are set, the water distributor, who is a member of the WUC, informs irrigation users about their schedule, often one to three days in advance.

3.2. Determinants of Household Contributions to Collective Irrigation Management

Collective irrigation management, in this case, is analyzed using the number of person days that farmers contribute, to clean and repair irrigation structures. Farmers are expected to clean and/or repair irrigation water structures such as canals, access roads and canal crossings.

3.2.1. Descriptive Analyses of Determinants of Household Contribution to Collective Action

The starting point for the analyses is to develop hypotheses based on a literature review and field observations.

Sex of the household head is an important consideration. It is expected that men contribute more working days towards the maintenance of irrigation structures than women. This is because women hold numerous responsibilities at home and on the farms, especially when they are heads of a household. Besides, cultural norms dictate that it is men who often work in the field.

The descriptive statistics in Table 2 support this idea. Female-headed households worked an average of 3.5 days while male-headed households worked an average of 5.4 days.

Table 2. Contribution to maintenance of irrigation structures by sex of household head (person days)

	Average number of days worked on cleaning and maintenance of irrigation structures
Male headed households	5.4
Female headed households	3.5

SOURCE: Authors' survey data

Another important input that differentiates benefits accruing to households from agriculture is land. The literature documents that private benefits associated with plot size determine water management (Yuko and Keijiro 2010; White and Runge 1994; Gaspart et al. 1998) as farmers with larger plots enjoy more benefits of well-cleaned channels and drainage. Hence, large cultivators would have more incentive to contribute towards collective action than small ones.

Table 3 examines the relationship between the size of the cultivated area and household contribution towards cleaning and maintenance of irrigation structures. Unlike the literature, Table 3 does not show a clear association of size of cultivated land and households' contribution to collective action. The number of days that households work on cleaning and maintenance of irrigation structures shows a continuous decline with a rise in cultivated land until it is reversed after three *timads* of land. This shows that the relationship may not be linear.

Table 3. Size of cultivated area and household contribution to cleaning and maintenance of irrigation structures (person days)

Size of cultivated land	Average number of days worked on cleaning and maintenance of irrigation structures
0.0 - 0.5	6.6
0.5 - 1.0	4.6
1.0 - 1.5	3.9
1.5 - 2.0	4.7
2.0 - 2.5	2.3
2.5 - 3.0	2.8
>3.00	4.8

SOURCE: Authors' survey data

One issue related to plot size is inequality in acreage under cultivation or landholdings theoretical predictions of the impact of inequality in landholdings on the provision of public goods, such as well-cleaned and maintained channels, are mixed.

One school of thought holds that a minimum threshold of land holdings exists, such that a group member who has land that exceeds this threshold contributes to the collective effort towards increasing irrigation water (Bardhan et al. 2006). This line of argument predicts that equality among contributors may be beneficial to the provision of public good to the extent that the average landholding exceeds the threshold level. A second line of argument stresses that inequality might be beneficial to the provision of public goods when a few members obtain a significant proportion of the total benefit from the public goods hence have strong incentives to provide them, even if they have to meet almost all costs (Olson 1965; Baland and Platteau 1997). The implication is that greater inequality in cultivation size may increase the provision of labour for collective irrigation management.

Table 4 compares household contribution to cleaning and maintenance of irrigation structures, with relatively equal or unequal land distributions. *Tabias* with equal or unequal land distributions are defined as *tabias* with a coefficient of variation of plot size less than or more than half of its average value. A plot in a *tabia* with larger inequality of plot size receives more irrigation water. Furthermore, a household in a *tabia* with unequal distribution of plot size contributes more towards the cleaning and maintenance of irrigation structures. These findings may be consistent with the argument of Olson (1965), who predicts that inequality may enhance the likelihood of collective action.

Table 4. Coefficient of variation of plot size in a *tabia* and household contribution to cleaning and maintenance of irrigation structures (person days)

	Average number of days worked on cleaning and maintenance of irrigation structures
<i>Tabias</i> with equal land holdings	6.8
<i>Tabias</i> with unequal land holdings	8.7

SOURCE: Authors' survey data

Labour is the other important input for agricultural practice. The labour contribution of households to collective action depends, among others, on the availability of labour and its opportunity cost. Farmers with high opportunity costs of labour may have lower incentive to cooperate in irrigation management. Educational attainment is a good proxy of the opportunity cost of labour associated with non-farm income (Yuko and Keijiro 2010). Table 5 summarizes the relationship between the educational

attainment of household members and household contributions to cleaning and maintenance of irrigation structures.

Educational attainment is measured by the average years of schooling of household members aged 15 and above. For descriptive analysis, we compare cases in which the average years of schooling of household members is less than or more than four years, which corresponds to the completion of the first cycle of primary education in Ethiopia. Table 5 demonstrates that households with highly educated members contribute less towards the cleaning and maintenance of irrigation structures.

Table 5. Number of adult household members, average years of schooling of adult household members and household contribution to cleaning and maintenance of irrigation structures (person days)

	Average number of days worked on cleaning and maintenance of irrigation structures
Average years of schooling less than or equal to four years	8.1
Average years of schooling more than four years	7.7
Number of adult household members less than three	7.8
Number of adult household members equal to or more than three	8.1

SOURCE: Author's survey data

A related determinant of household contribution towards cleaning of the channels is the number of adult household members. Since the agricultural labour market is imperfect due to the high monitoring cost of wage workers (Hayami and Otsuka 1993, cited in Yuko and Keijiro 2010), the supply of labour is significantly affected by the endowment of family labour. Thus, the number of adult household members may have a positive impact on the household contribution towards cleaning of canals. The lower panel of Table 5 compares household contribution to cleaning and maintenance of irrigation structures between two groups, where the number of adult household members is less than, or equal to, or more than its average of three people. Households with a large number of adult members are expected to contribute more towards cleaning and maintenance of irrigation structures than those with a small number of adult members.

Farmers' knowledge about different aspects of the rules and regulations of WUA in their respective localities is also included. Table 6 compares the contribution of farmers in this regard. It is reasonable to assume that knowledge of the norms, rules and regulations of WUA enhances farmers' commitment to collective action. The existence of written rules and

regulations is not sufficient by itself but gives a good orientation and understanding regarding the farmers' commitment to collective action.

Table 6. Knowledge of WUA norms, rules and regulations and household contribution to cleaning and maintenance of irrigation structures (person days)

	Average number of days worked on cleaning and maintenance of irrigation structures
Knowledge of water administration system	
No	8.0
Yes	8.1
Knowledge of regulation of protection and use of irrigation structures	
No	5.1
Yes	8.7
Knowledge of water distribution schedules	
No	5.6
Yes	9.6

SOURCE: Author's survey data

3.2.2. Regression Results – Determinants of Household Contribution Towards Cleaning and Maintenance of Irrigation Structures

Table 7 summarizes the regression results of the determinants of household contributions towards cleaning and maintenance of irrigation structures. The Tobit estimation method was employed as some of the farmers do not contribute towards cleaning and maintenance.

Among the variables that enter significantly, most are the individual farmer's knowledge about the norms, rules and regulations of water use associations, number of adult household members, and distance to Mekelle market.

Consistent to the study expectations, the number of adult household members enters positively and is statistically significant. The larger the number of adult members in a household, the greater the contribution of the household towards cleaning and maintenance of irrigation structures.

Table 7. Determinants of household contribution to cleaning and maintenance of irrigation structures (person days)

Variables	Coefficient
Household characteristics	
Sex of household head	-0.258
Number of adult hh members	1.178**
Average years of schooling of adult hh members	0.115
Size of irrigated area in <i>timad</i>	-3.303
Size of irrigated area squared in <i>timad</i>	0.627 (1.23)
Size of non-irrigated land in <i>timad</i>	-0.777
Size of non-irrigated land squared in <i>timad</i>	0.078
Geographical distance	
Distance to <i>woreda</i> market in kilometres	-0.298
Distance to Mekelle market in kilometres	-0.147*
Coefficient of variation of irrigation plot size in <i>tabia</i>	4.714
Knowledge of WUA rules and regulations	
Knowledge of water administration system	4.032**
knowledge of maintenance plan	6.451***
Knowledge of regulation of protection and use of irrigation structures	4.082**
Knowledge of water distribution schedule	5.963***
_cons	-3.272
Observations	289

SOURCE: Authors' survey data

Note: Absolute value of t-statistics in brackets. *significant at 10 percent; **significant at 5 percent;

*** significant at 1 percent

Most of the variables that define farmers' knowledge about the rules and regulations of WUAs entered with the expected sign and are statistically significant. Farmers with a sound understanding of the water administration system, knowledge of the maintenance plan of the WUA, knowledge about the regulations about the protection and use of irrigation structures, and knowledge of water distribution systems, contribute more towards cleaning and maintenance of irrigation structures.

To sum up, a good orientation on the rules and regulations of WUA enhances participation of farmers in collective action.

4. Multivariate Empirical Model and Results

4.1. Local Institutions and Water Use

In this section, the relationship between water management and functionality of local water use institutions is compared for the three study

sites. The functionality of the local water use institutions is indicated by how frequently irrigation users participate in the maintenance of the canals and other irrigation structures.

Table 8 gives details of the mean days of maintenance and cleaning works performed in the three irrigation schemes.

Table 8. Number of days spent on maintenance of irrigation schemes

Type of maintenance	Enderta	Atsibi	Samre
Dredging canals	2.78	1.5	1.5
Repairing canals	1.6	1.34	1.07
Repairing dam (shoulder)	0.71	0.48	0.44
Repairing weir	0.86	0.45	0.51
Repairing access road/bridge, canal crossing	0.28	0.34	0.45
Mean number of days of maintenance	7.08	4.26	4.08

SOURCE: Authors' survey data

4.1.1. Water Use by Area

Lack of information on measured water use per crop in the study sites necessitated usage of the survey data on irrigation hours per plot per crop. From the survey data, an average of the number of hours of irrigation per crop was obtained for each village. Household average water use of certain crops is the average of water use of all the plots that plant this crop. Finally, each village got an average estimation on irrigation water use by crop. This information was applied to each sample household and multiplied by the frequency of irrigation per week and number of weeks the plot was irrigated in one production cycle. Total water use in the sample land plots of farm households was then obtained.

The following table shows water use per *timad* by crop type, expressed in mean number of hours that a household watered its fields in one production cycle.

Table 9. Water use by crop per *timad* in number of hours of irrigation

Type of Crop	Enderta	Atsibi Wonberta	Seharti Samre
Cereals and pulses	68.07	62.35	64.08
Vegetables	100.31	112.1	125.46
All crops	93.79	67.14	64.73

SOURCE: Authors' survey data

The table indicates variation in water use in the three study sites. However, considering the overall water use, it appears that there is more water use in Enderta followed by Atsibi Wonberta, and the least in Seharti Samre. This order is in line with the mean number of days of maintenance (an indicator used to show the functionality of local water use institutions) stated above.

4.1.2. Determinants of Water Use

Table 10 indicates the link between water use and its determinants, following the multivariate specification shown in section 2.3.2.

Table 10. Determinants of crop water use per *timad* at household level

	Water use per <i>timad</i>	
	OLS	2SLS
Labour man days on maintenance	22.194*	32.054*
	(-1.78)	(-2.58)
Age of household head	5.478	4.815
	(-0.8)	(-0.72)
Squared age of household head	-0.044	-0.039
	(-0.62)	(-0.56)
Sex of household head	-16.866	-22.609
	(-0.51)	(-0.69)
Education of household head	-3.817	-4.292
	(-0.77)	(-0.87)
Share of village area covered by vegetables	74.235***	82.066***
	(-4.06)	(-4.53)
Fertilizer used per <i>timad</i>	0.028	0.034
	(-0.62)	(-0.75)
Proportion of land irrigated	99.103**	89.758**
	(-2.84)	(-2.61)
Constant	106.126	182.289
	(-0.54)	(-0.94)
Adjusted R-squared	0.104	0.102
Observations	289	289

SOURCE: Authors' survey data

Note: Absolute value of t-statistics in parenthesis; *significant at 10 percent, ** significant at 5 percent; *** significant at 1 percent

Besides functionality of local institution indicated by number of labour man days spent on maintenance of irrigation structures, a number of other variables that explain water use were included in the multivariate analysis. The variables include age and its squared, sex of household head, level of education of household head, and some cropping structure and production environment variables such as use of fertilizer per *timad*, proportion of a household's land irrigated, and share of village irrigated area covered by vegetables.

The empirical estimation performs well. Many coefficients on the control variable have the expected sign and some are statistically significant. For example, proportion of land of a household irrigated and proportion of irrigated land of a village covered by vegetables are statistically significant. After holding other factors constant, water use is higher in villages where the proportion of land irrigated is higher. Moreover, other factors held constant, households that are in villages with more vegetable area use more water per *timad* than other crops.

After holding constant other factors, our results show that the strength or functionality of WUA as shown by contribution of water users to maintenance of irrigation structures in person days, positively influences the use of water. That is, the more functional a water use institution is, the better is its water usage.

Although the above relationship is interesting, it is possible that the estimated parameter is biased since water use per *timad* may be determined simultaneously, with the functionality of water use institutions indicated by participation in collective action, or the estimated coefficient may be affected by unobserved heterogeneity.

In order to control for a potential endogeneity of functionality of water use institutions in the water use equation, an instrumental variable (IV) approach was adopted. To do so, prior to estimating equation (1) above, a set of variables is regressed against the water management institution variable, M_k :

$$M_k = \alpha + \beta IV_k + \delta Z_k + \varepsilon_k \dots\dots\dots (5)$$

where the predicted value of M_k from equation (5), $\hat{M}_k$, would replace M_k in equation 1. Equation (5) includes Z_k , which represents village and household level factors that affect water use.

A crucial question in instrumental variable IV approach is the validity of the instruments — the variables must satisfy the definition of instruments. The instrumental variables used to address the endogeneity problem are the number of times the water committee meets in a year and the duration of the establishment of water use rules and regulations. It is expected that the higher the number of times the water committee meets, the better they organize water users for collective action, which would strengthen the functionality of the local institution. Similarly, the longer the duration of the adoption of the water use rules and regulations, the better the opportunity for water users to understand and practice the rules, which would enhance their participation in collective action. Hence, contributing to the functionality of the WUA.

When putting the predicted value of the irrigation management variable into the water use model in equation (1), our results reflect little change and largely support the findings from the OLS model (Table 10, column 2). Compared with OLS estimation, the magnitude of the coefficient rises,

suggesting that the water use efficiency is large, if not greater than indicated by the results of the model estimated with OLS.

4.2. Water Management, Production, Income and Poverty

It is expected that the more functional a water use institution is, the better is the water management, and this positively influences production and hence income and/or poverty levels. Functionality of water use institutions and impact on agricultural production and agricultural income is examined in this subsection. The incidence of poverty is also analyzed.

Table 11 shows the crop yield per *timad*, for cereals and vegetables. The table indicates that agricultural inputs – labour, fertilizer and oxen power – are the major determinant factors of crop yield of both types of crops. These factors not only entered with expected signs but are also statistically significant.

The impact of functionality or strength of WUAs on agricultural production is measured through water use per *timad* of irrigated land. The study findings indicate the water use variable positively enters for both cereals (including pulses) and vegetables but is statistically significant for vegetables. This indicates that a better functioning local water use institution enhances water use, which may in turn boost yield of vegetables. This seems plausible because vegetables require more water and closer follow-up than cereals. The stronger the local water use institution, and hence better water usage, the higher the yield of vegetables. However, this does not apply equally in the case of cereals.

Table 11. Determinants of crop yield

	Crop yield per <i>timad</i>	
	Cereals (including pulses)	Vegetables
Log of water used per <i>timad</i>	0.021 (0.21)	0.846*** (3.59)
log of labour used per <i>timad</i>	0.218* (2.25)	0.477* (1.86)
Log of fertilizer used per <i>timad</i>	0.103* (1.7)	0.128 (0.83)
Log of oxen power used per <i>timad</i>	0.280* (2.46)	1.244*** (4.00)
Village dummy_Atsubi	-1.284*** (5.20)	-4.023*** (9.21)
Village dummy_Samre	-1.083*** (4.39)	-6.207*** (14.19)
Age of household head	0.012 (0.35)	0.054 (0.64)
Squared age of household head	0 (0.68)	-0.001 (0.73)
Sex of household head	0.108	-0.28

	(0.73)	(0.68)
Education of household head	-0.03	0.046
	(1.22)	(0.73)
Constant	6.549***	3.061
	(6.77)	(1.3)
Adjusted R-squared	0.174	0.492
Observations	202	289

Note: Absolute value of t-statistics in parenthesis; *significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent

SOURCE: Authors' survey data

Table 12 shows determinants of agricultural income. The functionality of local water use institutions as indicated by number of person days spent on maintenance is not significant in determining income from irrigation agriculture. Rather, only factors such as size of irrigated land, size of non-irrigated land, number of adult household members, and share of irrigation land covered by vegetables appear to be statistically significant. Irrigation income increases with an increase in size of irrigated land. Moreover, households with more adult household members earn more agricultural income and farmers in villages that grow more vegetables earn more agricultural income than farmers in the other villages.

To show the relationship between poverty and water use institutions, the consumption approach whereby consumption per adult equivalent is calculated was used to determine poverty in the study area. The national poverty line reported by the Ministry of Finance and Economic Development (MoFED) for 2010/11 adjusted by consumer price index, was used to delineate the poverty line. For comparison purposes, the international poverty line of US\$1 was also used. However, results are similar and only determinants of poverty based on the national poverty line is reported here.

Table 12. Determinants of farmers' income

	Cropping Income per capita	
	OLS	2SLS
Labour man days in maintenance	106.776 (-0.88)	105.251 (-0.87)
Age of household head	-56.231 (-0.91)	-56.279 (-0.93)
Squared age of household head	0.346 (-0.55)	0.346 (-0.57)
Sex of household head	32.017 (-0.11)	31.44 (-0.11)
Education of head	-56.634 (-1.31)	-56.661 (-1.34)
Size of land irrigated	606.544** (-2.91)	605.867** (-2.97)
Size of land not irrigated	-169.842* (-1.80)	-169.381* (-1.83)
Number of oxen owned	122.411 (-0.95)	122.716 (-0.97)
TLU excluding oxen	-6.637 (-0.11)	-6.773 (-0.12)
Number of adult household members	374.590*** (-4.21)	374.620*** (-4.31)
Share of irrigation land covered by vegetables	980.314*** (-4.75)	981.528*** (-4.85)
Proportion of land irrigated	-363.267 (-0.86)	-362.691 (-0.88)
Constant	3145.148* (-1.86)	3153.923* (-1.9)
Adjusted R-squared	0.353	0.353
Observations	289	289

Note: Absolute value of t-statistics in parenthesis; *significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent

SOURCE: Authors' survey data

Table 13 shows the result. The model performs well and produces robust results that largely confirm a priori expectations. Coefficients of the control variables in the model were of expected sign and statistically significant. For example, the relationship between poverty and age of household head is non-linear. It is negative at a young age and positive at old age. Similarly, asset ownership, especially land and livestock, and cultivation of vegetables rather than cereals through irrigation, are inversely related to poverty.

Of great significance, research results demonstrate that functionality of WUA has no apparent impact on the poverty status of the sample households. As stated above, it is the individual characteristics of the farmer such as age, productive asset holdings, family size, and whether the farmer grows more of market- oriented high value crops such as vegetables, rather than the strength or weakness of WUA in water use management.

Table 13. Determinants of Poverty

	Dummy Poverty		
	Probit	IVProbit	2SLS
Labour man days in maintenance	-0.006 (-0.07)	0.012 -0.13	-0.003 (-0.09)
Age of household head	-0.087* (-1.71)	-0.088* (-1.72)	-0.030* (-1.86)
Squared age of household head	0.001* -1.9	0.001* -1.92	0.000* -2.02
Sex of household head	0.156 -0.63	0.162 -0.65	0.044 -0.55
Education of head	0.002 -0.07	0.003 -0.09	-0.002 (-0.23)
Size of land irrigated	0.013 -0.09	0.021 -0.14	0.005 -0.1
Land owned (excluding irrigation)	-0.095* (-1.72)	-0.100* (-1.81)	-0.032* (-1.81)
Livestock ownership in TLU	-0.095* (-2.51)	-0.096* (-2.54)	-0.028* (-2.46)
Family size	0.336***	0.339***	0.108***
Share of irrigation land covered by vegetable	-6.01 -0.276* (-1.71)	-6.02 -0.292* (-1.81)	-6.64 -0.089* (-1.72)
Constant	0.22 -0.17	0.129 -0.1	0.651 -1.57
r2_a			0.177
bic	395.05		
athrho		-0.089 (-1.10)	
Insigma		-1.850*** (-44.48)	
N	289	289	289

SOURCE: Authors' survey data

5. Conclusions

Water, as a natural asset, forms part of the asset range available to households. Improved access to water supply plays a critical role in enabling sustainable livelihoods of households. One way in which this natural resource benefits households is through irrigation. The government of Ethiopia has emphasized on water harvesting and sustainable irrigation development as focal points of development strategy in its Growth and Transformation Plan (GTP). Following the national GTP framework, the GTP of the regional government of Tigray emphasizes agriculture, agricultural-based industrialization and improving access to safe drinking water and sanitation, as primary goals for social and economic development. Over the planning period (2010/11-2014/15), targets are set to construct and maintain 100,515 water banks that can be managed by households and the society, so as to enhance irrigation from 83,000 to 350,000 hectares at the end of the planning period (BPF 2010).

However, developing the water resource is one challenge and efficient utilization of the water is another issue. It is sensible, therefore, to examine how water is used in existing irrigation systems, with a view to managing its use efficiently. This study assessed the importance of local level WUA in water utilization, hence the impact on income and poverty levels of irrigation water users, by analyzing three irrigation schemes. All the irrigation schemes are administered by WUA. The strength and/or functionality of water use associations was assessed by collective action — the number of days irrigation users work on cleaning and maintaining irrigation structures. Significant differences were noted in the collective action in the three irrigation schemes. Irrigation users in Enderta work more days in cleaning and maintaining irrigation structures followed by users in Atsibi Wonberta and finally in Seharti Samre.

Taking collective action as a proxy to measure strength of WUA, we found strong and positive correlation between a well functioning WUA and water utilization. After holding constant other factors, our results show that the strength or functionality of local water use institutions, as shown by contribution of water users to collective action, positively influences the use of water. That is, the more functional a water use institution is, the better is the water usage. This supports the growing idea that small-scale community based irrigation management is required in developing countries, to improve efficiency and reduce costs.

Further, by categorizing the irrigation crops grown into three – cereals, pulses and vegetables – the paper relates the functioning of local institutions to productivity. Results revealed that crop productivity is mainly influenced by the use of agricultural inputs – labour, fertilizer and oxen power. However, a well functioning local water use association influences productivity of high value cash crops, such as vegetables, through improving water use efficiency. This indicates that a better functioning local water use institution enhances water use, which may in

turn boost yield of vegetables. However, similar results were not observed with the traditional crops such as cereals and pulses. This seems plausible because vegetables require more water and close follow-up compared to cereals and pulses.

After correlating the functioning of local institutions with agricultural productivity, the paper analyzed whether or not such a correlation influences household income directly, and hence lesson poverty. Despite a correlation of local institutions with productivity of high value crops such as vegetables, the paper could not find any evidence that a well functioning local institution affects household income directly. Household income, and hence poverty level, is mainly affected by individual household characteristics such as age and sex of household head, size of land irrigated and proportion of irrigated land used to grow vegetables rather than by collective action. It seems apparent that a well functioning local institution only prepares a level ground for irrigation users. Whether and how irrigation users use the opportunities laid down by local institutions depends on their individual characteristics, which in turn affect their income level and hence poverty.

Notes

1. Correspondence address: Fredu Nega, HESPI, Addis Ababa, Ethiopia. Email: tfredu@yahoo.com
2. *Woreda* is the second administrative unit above *tabia*
3. *Tabia* is the smallest unit of local government in rural communities in present day Tigray.
4. E.C stands for Ethiopian Calendar

References

- Baland, J. M. and Platteau J. P. 1997. Wealth inequality and efficiency in the commons: The unregulated case. *Oxford Economic Papers*. New Series. 49(4): 451-482.
- Bardhan, P., Maitreesh, G. and Alexander, K. 2006. Wealth inequality and collective action. BREAD Working Paper 113.
- BoPED (Bureau of Planning and Economic Development), 1995. Five Year Development Plan of the Tigray Region. Mekelle, Ethiopia.
- Bureau of Planning and Finance (BPF). 2010. Tigray Regional State: Five Years (2010/11–2014/15) Growth and Transformation Plan. Mekelle, Ethiopia.
- Central Statistical Agency of Ethiopia (CSA). 2007. The 2007 national statistics. Retrieved August 20, 2013, from

http://www.csa.gov.et/text_files/national%20statistics%202007/Agriculture.pdf

Federal Democratic Republic of Ethiopia (FDRE). 1996. *Food security strategy*.

Addis Ababa, Ethiopia.

_____. 2002. *Food security strategy*. Addis Ababa, Ethiopia

_____. 2010. *Growth and transformation plan, 2010/11 – 2014/15*. Addis Ababa, Ethiopia.

Fredu, N., Zaid, N., Kidanemariam, G., Abebe, E., Mihret, B., Nyssen, J., Bedru, B., Deckers, J. and Tollens, E., 2006. Participatory rural appraisal report of selected villages in Tigray. Tigray Livelihood Papers No.2 VLIR – Mekelle University IUC Programme, Ethiopia.

Gaspart, F., Mohammad, J., Catherine, M. and Jean-Philippe, P. 1998. Participation in the construction of a local public good with indivisibilities: An application to watershed development in Ethiopia. *Journal of African Economies* 7(2): 157-184.

Gebremedhin, B. and Pedon, D. 2002. Policies and institutions to enhance the impact of irrigation development in mixed crop-livestock. Proceedings of a MoWR/EARO/IWMI/ILRI international workshop held at ILRI, December 2–4, Addis Ababa, Ethiopia.

Gebremedhin, B., Pender, J., Ehui, S. and Haile, M. 2002. Policies for sustainable land management in the highlands of Tigray, Northern Ethiopia. Summary of papers and proceedings of a workshop, March 28-29, Axum Hotel, Tigray, Ethiopia.

Hayami, Y. and Keijiro, O. 1993. *The economics of contract choice: An agrarian perspective*. Oxford: Clarendon Press.

Hussain, I. and Hanjra, M. A. 2004. Irrigation and poverty alleviation: Review of the empirical evidence. *Irrigation and Drainage*, 53: 1-15.

Olson, M. 1965. *The logic of collective action*. MA: Harvard University Press.

Tekleyohannes, H. 2011. The impact of small-scale irrigation on improving household income: The case of Haiba micro-dam at Seharti Samre *Woreda*, Southeastern Zone, Tigray Regional State. MSc. thesis, Mekelle University.

Tsehaye, A., Tadesse, D., Declerck, S., Nyssen, J., van der Gucht, K., Risch, S., Roussaux, S., De Wit, J., Afework, M., Nigussie, H., Abreha, G., Poesen, J., Deckers, J., Vyverman, W. and De Meester, L., 2007. Ecological atlas of reservoirs in Tigray, Northern Ethiopia. Tigray Livelihood Papers No.4 VLIR, Mekelle University IUC Programme.

White, T. A., Runge, C. F. 1994. Common property and collective action: Lessons from cooperative watershed management in Haiti. *Economic Development and Cultural Change* 43 (1): 1-41.

Yuko, N. and Keiji, O. 2010. Determinants of household contributions to collective irrigation management: A case of the Doho Rice Scheme in Uganda.

Paper presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23.

Assessment of the Impact of Innovations in Water Resource Management on Poverty in Wakiso District, Uganda

Jamil Serwanga and Faisal Buyinza

Abstract: This study set out to assess the impact of innovations in water resource management on poverty reduction in Wakiso District, Uganda. Data for the study comprised primary data that was collected from respondents using a structured questionnaire and supplemented with personal interviews. The study used both qualitative and quantitative statistical techniques to analyze the sample data collected from 300 households from the sub-counties, Kakiri, Nabweru and Nangabo of Wakiso District. The findings of this study generally suggest that understanding households and their socioeconomic settings, and matching this with the appropriate policy framework is fundamental for sustainable water management for poverty reduction.

Key words: poverty, management, innovation and water resources

1. Introduction

1.1 Background to the Study

This study set out to assess the impact of innovations in water resource management on poverty reduction in Wakiso District in Uganda. Water is a global and crucial issue. It is directly and indirectly, the first cause of death and disease in the world. Thus, water is a precious natural resource, vital for animal, plant and human life. Water as a resource is also highly needed for development and environmental sustainability. When water is too much or too little, it can cause destruction, misery or death in the community. However, proper water management is an instrument for economic survival and growth. The United Nations (UN-WATER/AFRICA, 2004) notes that water can be an instrument for poverty alleviation. It is also noted that good water resources management can lift people out of the degradation of having to live without access to safe water and sanitation. Prosperity for all will be achieved through innovative water uses and management as linked to agricultural sector transformation and development. However, when water is inadequate, either quantitatively or qualitatively, it is a limiting factor in poverty alleviation and economic recovery, resulting in poor health, low productivity, food insecurity and constrained economic development of both rural and urban communities, especially in least developed countries, Uganda inclusive. The United Nations estimates that 1.1 billion people globally do not have access to safe drinking water and 2.6 billion still lack basic sanitation. Although it is unevenly distributed,

there is plenty of water for everyone in the world, but poor management explains why many people do not have access to water.¹

Water plays a pivotal role in sustainable development, including poverty reduction. The role that water plays in the livelihoods in the rural areas in the developing world is manifold; it is for agriculture and domestic uses. With land, it is argued that water is the most critical input into sustaining livelihoods in Africa (Hope and Gowing 2003). The use and abuse of increasingly precious water resources has intensified dramatically over the past decades, reaching a point where water shortages, water quality degradation and aquatic ecosystem destruction are seriously affecting prospects for economic and social development, political stability and ecosystem integrity (UNDP 2007). Given the importance of water in poverty alleviation, human health and ecosystem stability, the management of water resources assumes a vital significance for the socioeconomic development of rural communities in Uganda (Uganda Bureau of Statistics (UBOS) 2010). The growing economic and physical scarcity of water, coupled with rising costs of developing additional sources of water to meet the increasing demand, calls for innovative ways of water use and management in most developing countries, including Uganda. The innovations in water use and management are expected to contribute greatly towards poverty reduction, especially in rural areas where agriculture is the major activity and source of livelihood.

Uganda is one of the poorest countries of the world, where more than 80 per cent of the population live in rural areas and depend on agriculture for their livelihood (UBOS 2010). Uganda's agricultural sector is mainly rainfed and activities are done using basic technologies. Mechanization is minimal (applied in few instances of plantation farming) and the land is highly fragmented. This has made the participants in the agricultural sector, mainly farmers and pastoralists, to be more vulnerable to climate variability. The widespread poverty in Uganda, mainly in the rural areas, is mainly explained by the low productivity in the agricultural sector, which is worsened by recurring drought as agriculture in Uganda is basically rainfed (World Bank 2008). Innovations in water use and management are expected to contribute greatly towards poverty reduction in the rural areas of the world. This is linked to the influence of water on the growth of a country and alleviation of poverty via the agricultural sector development given its forward and backward linkages.

In July 1995, the Uganda Water Action Plan was launched to provide guidelines and strategies for the management of the country's water resources (Uganda National Water Report 2005). In addition, the plan examines Uganda's international obligations for equitable and sustainable utilization of the Nile waters. Among others, Uganda desires to provide a basic water supply of 20 litres of safe and clean water per capita per day within a reasonable walking distance (maximum 1.5 kilometres) for every rural household, and achieve a source-person ratio of 1:300 for hand-pump

supplies and 1:500 for protected springs/wells in rural areas exhibiting national average population densities of 85 persons per square kilometer or more (Uganda National Water Report, 2005). Access to water, for both domestic and productive purposes would be a very real and tangible benefit for the poor. However, the financial resources are limited in most developing countries.

In Uganda, access to improved water in 10 per cent of the districts is under 20 per cent while functionality of water points in 5 per cent of the districts is below 60 per cent (Directorate of Water Development — Uganda 2010). It is clear that such a situation would hinder faster rates of poverty reduction in the rural areas of Uganda where agriculture is the major economic activity and source of livelihood. Uganda is well endowed with water resources, both surface and underground. The country has 42,942 km² of surface water, which accounts for 18 per cent of the total geographical area, and much of the country receives over 750 millimetres of rainfall annually (Government of Uganda, Plan for Modernization of Agriculture (PMA) 2000). There has been growing attention to water policies and water use in Uganda, as demand for quantity and high quality water grows beyond sustainable levels of natural supply. This situation is another call for urgent innovations in water resource use and management in the country, for sustainable development. Many countries have already introduced measures to provide greater incentives to water users for efficient management such as pricing, irrigation management transfer, and engaging the private sector in distribution and water management (Uganda National Water Development Report 2005). This is based on the fact that lack of water is a tragedy for many poor people and also causes problems to the natural environment. Globally, water scarcity already affects four out of every 10 people and more than 30 countries face water stress and scarcity virtually throughout the year. Further, it appears that one of the main factors limiting future food production in Uganda and other parts of the world is water (Uganda National Water Development Report 2005).

1.2 Statement of the Problem

Despite the existence of various major water bodies in Uganda, such as Lake Victoria, Lake Kyoga, River Nile, River Katonga, a variety of streams and springs, plus two rainy seasons (April-July and September-November), a number of communities in Uganda, especially in rural areas, still face inadequate supplies of water for domestic consumption, and crop and animal production. This is regardless of existing water development projects and programs, such as Rural Water and Sanitation, and a Water Development Plan under the Ministry of Water and Environment. Farmers and pastoralists are the most affected groups of people. This could be due to inadequate innovative use and poor management of water resources in affected communities. If not given due consideration, this situation is likely to worsen the incidence of poverty in the rural areas of Uganda. Due to poverty, access to adequate water and sanitation is minimal in the rural

areas of Uganda (Uganda Bureau of Statistics <UBOS> 2010). This study, therefore, assessed the extent and determinants of innovations in water use and management for sustainable development, including poverty reduction, in Wakiso District of Uganda, with specific reference to the sub-counties of Nansana, Kakiri and Nangabo.

1.3 Objectives of the Study

This study aimed at assessing the impact of innovations in water resource management on poverty reduction in Uganda. The study specifically attempted to answer the following questions:

- (i) What are the existing water sources for poverty reduction in Wakiso District?
- (ii) What are the existing water management strategies for poverty reduction in Wakiso District?
- (iii) What is the level of “social solidarities” or the willingness of stakeholders to adopt and/or implement new water management measures for poverty reduction in Wakiso District?
- (iv) What is the extent to which irrigation (water) is used to increase agricultural productivity for poverty reduction in Wakiso District?

1.4 Study Methodology

The data for the study comprised primary data that was collected from respondents using a structured questionnaire, and supplemented with personal interviews. A household survey questionnaire was used to collect information on socioeconomic variables of households in relation to innovation options in water use and management in Wakiso District, in the Central region of Uganda. The data collected included socioeconomic characteristics of the households, their access to clean water, time taken to collect water, involvement in water resources management, and purpose for the innovation options. Data related to the constraints experienced in the acquisition of better water innovation options were also collected. The study used both qualitative and quantitative statistical techniques to analyze the sample data collected from 300 households from Kakiri, Nansana and Nangabo sub-counties of Wakiso District.

The employed model is described as follows. For an individual i , we consider the standard Tobit model (Tobin 1958), as quoted by Maddala (1981: 163) and expressed as:

$$y_i^* = X_{hi} \beta_w + \varepsilon_{hi}, \forall i = 1 \dots n \quad (1)$$

In equation 1, above, y_i^* is a latent variable which satisfies the properties of the linear model. That is, it is a binary variable equal to 1 if the

i^{th} individual is using piped water or protected spring or rain harvested water, and is equal to zero otherwise. This response is determined by the latent variable y_i^* . In order to parametrically estimate the model, X_i is the set of exogenous (independent) explanatory variables, β is a vector of parameters to be estimated and ε_i is the error term normally distributed with mean zero and constant variance.

$$y_i = \begin{cases} y_i^* = 1: & \text{if } y_i^* > 0 \\ y_i^* = 0: & \text{if } y_i^* \leq 0 \end{cases} \quad (2)$$

From Equation 2, y_i is a binary variable equal to 1 if the i^{th} individual is using piped water or protected spring or rain harvested water, and is equal to zero otherwise. This response is determined by the latent variable y_i^* .

With the assumption that ε_i follows the normal distribution with mean zero and variance σ_ε^2 and is independent across individuals, equation (2) represents a conventional Tobit model which can be estimated consistently by a maximum likelihood estimator. A maximum likelihood estimator (the appropriate estimator for Tobit models) is used to estimate these parameters. If we estimate by maximizing the underlying likelihood, we have the density of a household which participates in water uses innovation and management $h_i > 0$ given by the following expression:

$$f(h_i | x_i) = f(\beta_0 x_i + \varepsilon_i | x_i) = \left(\frac{1}{\sigma_0}\right) \phi\left(\frac{\varepsilon_i}{\sigma_0}\right) \quad (3)$$

In addition, the probability that a household does not participate in water use innovations and management ($h_i = 0$) is given as:

$$\Pr(h_i = 0 | x_i) = \Pr(\beta_0 x_i + \varepsilon_i \leq 0 | x_i) = 1 - \Phi\left(\frac{\beta_0 x_i}{\sigma_0}\right) \quad (4)$$

Thus, writing both equation 3 and 4 simultaneously, we obtain the following expression:

$$f(h_i | x_i) = \left[\left(\frac{1}{\sigma_0}\right) \phi\left(\frac{h_i - \beta_0 x_i}{\sigma_0}\right)\right]^{1(h_i > 0)} [1 - \Phi\left(\frac{\beta_0 x_i}{\sigma_0}\right)]^{1(h_i = 0)} \quad (5)$$

Therefore, the likelihood for observation i is given as equation 5. Maximizing the underlying likelihood function of equation 2, we are able

to obtain estimates of β as well as the probability of water use innovations and management:

$$L_i(\beta, \sigma) = 1(h_i > 0) \log \left(\frac{1}{\sigma} \phi \left(\frac{h_i - \beta x_i}{\sigma} \right) \right) + 1(h_i = 0) \log \left(1 - \Phi \left(\frac{\beta x_i}{\sigma} \right) \right) \quad (6)$$

The values of the Tobit model estimates do not directly correspond to changes on the dependent variable as a result of a unit change of the explanatory variables. Rather, normalised coefficients are reports which can be transformed into first-order derivatives. The marginal effects of the explanatory variables on the observed variable represents the expected value of y_i conditional on y_i being greater than zero.

From Equation 6, ϕ denotes the cumulative standard normal distribution. Because the results of this study are of interest to policy recommendations, the marginal effects on the observed values of the dependent variables, due to a 1 per cent change given on the independent variables, is a valuable result of the Tobit analysis.

Analysis of household-level determinants of water use is another objective of this study. To achieve this, the total household water use per day at household level per capita (per every member of the household) was taken as the dependent variable. Thus, water use at household level was to be influenced by a number of factors. It is hypothesized that a household with one or more individuals would inevitably use higher amounts of water per day at the household level and the per capita water use per day at an individual level, all different from zero. The variation is hypothesized to occur due to other factors such as household size, average waiting time at source, convenience of location of the water source, its physical location, and the estimated distance of the water source from the household. Thus, the relationship between the dependent and independent variables in this case can best be represented by a linear regression model as presented below in equation 7.

$$Y_i = \beta_0 + \beta_1 hsize_i + \beta_2 Wtime_i + \beta_3 Wdist_i + \beta_4 location_i + \varepsilon_i \quad (7)$$

From Equation 7, **hsize** denotes the household size, **wtime** is the average time spent by household members in collection of water, **wdist** is distance travelled on average by households to fetch water from the different available water sources, and **location** is the actual water source location. The last term ε is a random normally distributed error term.

2. Reviewed Literature

In this section a review of literature is performed concerning the influence of water in the process of poverty reduction in different parts of the world. Challenges to increase water supplies, especially in the rural areas in developing countries, are also surveyed in the literature. Both theoretical

and empirical studies indicate that water is a source of life. Sharma et al. (1996) note that water is a commodity of strategic importance because of increasing demands and rising costs, coupled with diminishing supplies. The authors further note that it is no longer feasible in a long-term, cost-effective and environment-friendly manner, to increase water supply by building additional dams and conveyance systems, sinking new wells or building desalinisation plants. According to Sanstrom (1997), it is now recognized that solutions must be found at the user-end of the pipe, which improves water use, productivity, reducing conveyance losses, reusing water, and optimising allocation. Also, Sharma et al. (1996) and Karikari (1996) note that water is a scarce commodity with dimensions of economic efficiency, social equity and environmental sustainability. The conclusion drawn from these studies is that water has both public and private characteristics, hence both public and private sectors have an important role to play in the efficient management and development of water, particularly communities that use water for production as an input in various production processes. Further, in designing water scarcity solutions there is need to take responsibility by conserving, recycling and protecting water sources more efficiently.

Innovations in water management and use, in the context of the study, are concerned with the planning, design, implementation, and maintenance of a water project or programme, to ensure that water as a resource is efficiently and effectively utilized by the community, for welfare improvement. Water management involves the participatory approach of empowering communities, especially women, to provide, protect and safeguard their own water sources. The interdependence between water availability and development is exemplified by the link between water and poverty (Hope and Gowing 2003). As a result of inadequate access to safe water, there is a high incidence of communicable diseases, which reduce vitality and economic productivity in the affected areas. Inadequate access to water and sanitation is thus both a cause and a consequence of poverty. Similarly, inadequate water resources can become a constraint to improved agricultural development and food security, hence exacerbate poverty levels in different communities (Serwanga 2006).

Global Envision (2013) notes that African countries will be hard pressed to emerge from poverty due to poor water management and not lack of available water. "There is enough fresh water in Africa for everybody, but management of water resources is less than optimal."² What is needed most, are innovations in the management of water resources in the different parts of the world. It is further observed that in water-scarce North Africa, good water management is the reason why countries in the region use more of available water than water-rich Sub-Saharan Africa. It is indicated, for example, that Algeria uses 42 per cent of its available water while the Democratic Republic of Congo, which has twice as much water, only uses 0.03 per cent.³ This serves as a caution to countries such as Uganda, where

an abundance of water sources is available but not put to effective use in production processes, for poverty reduction.

Because of the link between water and food production, there is a strong positive trend in rural water coverage, in Uganda from around 20 per cent at the start of the 1990s to around 60 per cent currently (Uganda Water Atlas as quoted by Ministry of Finance, Planning and Economic Development (MFPED) 2011). Consequently the time saved by the children, spared from fetching water over long distances, permits them to attend school more appropriately (Hope and Gowing 2003). Shortage of water also affects the quality of health care and education.⁴ The cost of investment in rural water supply makes it almost prohibitive as an upfront investment for most rural communities. There is, however, more scope for private sector involvement in rural growth centres, small towns and urban centres where population densities are higher. Reports indicate that the government of Uganda has assumed responsibility for most of the costs of rural water supply. As a result, access to rural water supplies increased to an estimated 61.3 per cent in 2004/5. This was achieved through new water facilities, which provided improved water supplies to an estimated additional 680,000 people. The new facilities include piped water schemes for eight Rural Growth Centres (RGCs) and for seven Internally Displaced Peoples (IDP) camps in Northern Uganda (Uganda National Water Development Report 2005). Thus, under all circumstances, governments are a key factor in improving water supply for poverty reduction.

The United Nations (2011) notes that in most least developed countries, agriculture is a mix of rainfed and irrigation farming. At the international scale, rainfed farming is the world's most common farming system, practiced on 80 per cent of cultivated land and accounting for 60 per cent of world food production. However, in areas of low, erratic and unreliable rainfall, such as the drier regions of Africa, crop yields are low and uncertain, because of less innovation in water management. This is not the case in more developed countries, where crop yields are good and production is reliable because of good water management systems. It highlights the importance of irrigation in the process of agricultural development for poverty reduction, especially in the least developed countries.

However, at the international scale, it is pointed out that irrigation is only practiced on about 300 million hectares, or 20 per cent of the cultivated land. It is also noted that the contribution of irrigation is substantial, with more than 40 per cent of the world's food production linked to irrigation or generally good water management systems. Irrigated agriculture provides a great potential for economic growth and poverty reduction. This is true in the sense that irrigation can reduce the risks associated with the unpredictable nature of rainfed agriculture, especially in dry regions, and increase crop production. But all this must be combined with effective means of water control (United Nations 2011).

The water supply situation in Uganda indicates that expanding access to safe water and sanitation is one of the highest objectives of the Government's agenda. It is further reported that the proportion of the population with access to an improved water source currently stands at 70 per cent and 92 per cent in rural and urban areas, respectively. This compares favourably with 63.6 per cent and 86.8 per cent, in 2005/06. However, a high variation exists in access and water point functionality between districts. Access in 10 per cent of districts is under 20 per cent while functionality of water points in 5 per cent of the districts is below 60 per cent (Uganda Water Supply Atlas 2010) as quoted by MFPED, (Background to the Budget 2011/12). This is an indication of the need to assess innovations in water use and management, which can lead to higher water access levels and water point functionality, especially in the rural areas of Uganda.

Some key challenges still stand in the way of successful contribution of water management to poverty reduction, especially in least developed countries. These include achieving the sanitation targets, putting up the right infrastructure, securing finance, and considering water as a right (Poverty-Environment Partnership (PEP) 2005). United Nations (2011) points out that there is sufficient water to meet global needs in developing countries. However, it is up to the stakeholders, smallholder farmers, researchers, policy-makers and governments, to apply innovative agricultural water management technologies in order to address the growing food demands with finite water resources. In this regard, Asia is a good example of an area where water scarcity and agricultural water development are directly linked to extreme poverty and hunger, with about 700 million people living in extreme poverty (United Nations 2011). According to Mkherji et al. (2009), as quoted by United Nations (2011), irrigation farming in Asia accounts for 70 per cent of the world's irrigated area and almost one-third of the region's cropland. In the 1960s and 1970s, supply of water to smallholder farms was enhanced and provided the potential to drive Asia's green revolution.

In a bid to fight poverty, there is also a need to provide clean and safe drinking water. Opio (2012) observes that while the need to provide clean drinking water is widely recognized as a priority in rural Sub-Saharan Africa, there is lack of specific data on water quality to build effective drinking water management policies. This discussion paper describes a water quality study undertaken in Northern Uganda, to test the portability and potential contamination of water taken from wells, open water sources and households. Key lessons from the study include the fact that clean well water can be contaminated during transportation to, and storage in, homes.

The causes of poverty, especially in least developed countries such as Uganda, include low agricultural productivity because of extended drought (lack of water for the crops and animals), inadequate access to inputs, low levels of technology used in agricultural activities, limited access to credit,

and poor infrastructural development, more so, the road network which inhibits easy access to the market by peasant farmers (Serwanga, 2006; Kessy and Aiko, 2008). In these studies, it is noted that water as a resource and input to poverty reduction is not emphasized through innovations and management. Donaghy et al. (2006) also point out that agriculture is one of the sector's most sensitive to climate change, whereby climate change is expected to have profound impacts on activities in the sector as well as on other water resource-based activities. Todaro and Smith (2003) document that efforts must be made in order to improve on the performance of the agricultural sector in relation to climate change, in order to reduce the number of people living below the poverty line. The experience of the strategy of the green revolution would be of paramount significance here.

According to McCartney (2010), as quoted by United Nations (2011), it is observed that water storage is one of the major components of water management, and it has the greatest potential to deliver improvements in water management. That is, water storage is often associated with dams and environmental and social problems. In the case of environmental problems, there would be some flooding during some seasons while social problems may involve displacement of people.

Water harvesting, is an innovation that is crucial in the process of water management for poverty reduction, especially in the rural areas. Water harvesting has been practised in many parts of the world, although on a small-scale, especially in developing countries. Rainwater collection tanks for home use, is pointed out to be a simple solution that could create extraordinary gains.⁵ It is reported that in the rain harvest process and project, as initiated by Jack Rose in Kenya and Tanzania, schools have provided an excellent location for water harvesting tanks at village level. The schools are generally at the centre of villages and serve as a source of pride for many villagers. Once installed, teachers, students and parents act as the administrators of the water system and are responsible for the security and maintenance of the water storage tanks, and distribution of the water. A complete water harvest system consists of a water tank, rain gutters and a filter. Each system could be installed in a day.

Poor governance or resource mismanagement has been identified as a major cause of the world's water predicament (Hope and Gowing 2003). Under such circumstances, it is argued that, "...where there is water poverty", any measures to reduce income poverty are unlikely to be successful (Hope and Gowing 2003). This, therefore, highlights the need for innovations in water use and management, for poverty reduction, in countries whose economies are still largely based on agricultural activities.

3. Results

3.1 Innovations in Water Resource Management in Wakiso District, Uganda

It should be recalled that the study used primary data collected from personal surveys, using a structured questionnaire, supplemented with personal interviews from three sub-counties in the central region of Uganda. A household survey questionnaire was used to collect information on socioeconomic variables of households in relation to innovation options in water use and management. The data collected included socioeconomic characteristics of the households, their access to clean water, time taken to collect water, involvement in water resources management, and purpose of the innovation options. Information on the constraints faced in the acquisition of better water innovation options was also collected.

Analysis of the determinants of community participation in water use innovation and management also formed part of the major objectives of this study. The contribution of labour and money by the water users in the innovation and management (for the protection and maintenance) of water sources were taken as the major dependent variables, to understand their role. Independent variables were identified based on the reviewed literature and actual conditions in the area useful in explaining the variations in the dependent variables across households. An increase in the household socioeconomic and demographic variables, such as age of household heads, education level, gender, and household size, are hypothesized to positively affect water use innovation and management.

Data on some of the background characteristics of the study sample⁶ are presented in Table 1. Results in Table 1 indicate that Nangabo Sub-County has the highest proportion of women with secondary and postsecondary education (33 per cent and 9 per cent), and Nansana and Kakiri sub-counties have the highest proportion of women with primary education (64 per cent). Overall, the worst educational indicators are observed in Kakiri Sub-County, with only 1 per cent postsecondary education level. Furthermore, Table 1 shows that across the three sub-counties, Nansana had the highest proportion (70 per cent) of married women while Nangambo had the least proportion (52 per cent) of currently married women.

Table 1. Household gender, age and educational characteristics

Factors/Variables	Covariates	Nangambo	Nansa	Kakiri	Total
Family welfare:	Poor	19	41	28	39
	None poor	71	39	39	18
	Rich	18	20	33	43
Husband's education:	No education	8	14	22	21
	Primary	50	64	64	58
	Secondary	33	19	12	18
	Postsecondary	9	3	2	4
Employment status:	All year	70	39	55	46
	Seasonal	22	55	35	45
	Occasional	8	6	10	9
Source of water:	Piped water	35	5	16	16
	Boreholes	14	53	14	34
	Covered wells	19	23	25	20
Marital status:	Uncovered wells	32	19	45	30
	Married	52	70	61	65
	never	32	21	25	24
Religion:	Widowed	16	9	14	13
	Muslim	18	16	4	11
	Christian	45	54	53	44
	Catholic	37	29	43	45
Toilet facilities:	Flash	17	3	2	6
	Covered	67	61	80	65
	Uncovered	15	21	14	15
Land ownership:	Bush/No Toilet	1	15	4	14
	Personal land	42	7	8	17
	Rent	58	93	92	83

Source: Authors' computations from the survey (2013)

Table 1 indicates that 70 per cent of respondents in Nangabo Sub-County are employed all year, followed by respondents in Nansana Sub-County (55 per cent) and Kakiri Sub-County (39 per cent). Seasonal employment is more pronounced in Kakiri Sub-County (64 per cent) followed by Nansana Sub-County (55 per cent), whereas occasional employment is lowest in Nangabo Sub-County (8 per cent). Table 1 also shows that better sanitation was most lacking in the Nansana Sub-County (15 per cent) of the respondents had no toilet facilities. Poor sources of water and type of toilet facility are correlated with high disease infection rates. This result accentuates the importance of toilet facilities for good community health. In addition, the results show variations in the level of sub-county development. It is expected that more developed sub-counties have higher levels of infrastructural development. This implies that households that have piped water and flush-toilet facilities enjoy a higher standard of living,

and members in these households are likely to experience a very low rate of water- born related disease infections, compared to their counterparts who lack piped water and flush-toilet facilities.⁷

The data in Table 1 further reveals that in Nansana Sub-County, sanitation facilities are very poor, with about 15 per cent of the households lacking a toilet, hence go to the bush. In addition, the same sub-county had the highest percentage (21 per cent) of uncovered toilet facilities. Given the health implications of such poor sanitation facilities, there is a likelihood of a high rate of occurrence of diseases associated with poor sanitation in Nansana sub-county. A number of respondents called for assistance from the government and non-governmental organizations (NGOs), to come to their rescue and build community-based toilets as it is very costly for the communities to accomplish this due to substantial levels of poverty.

A number of water uses were identified by the households, which include domestic water uses, commercial car washing, brick making, irrigation farming, and water selling businesses. Figure1 presents the sources of distribution of drinking water in the three sub-counties that were visited.

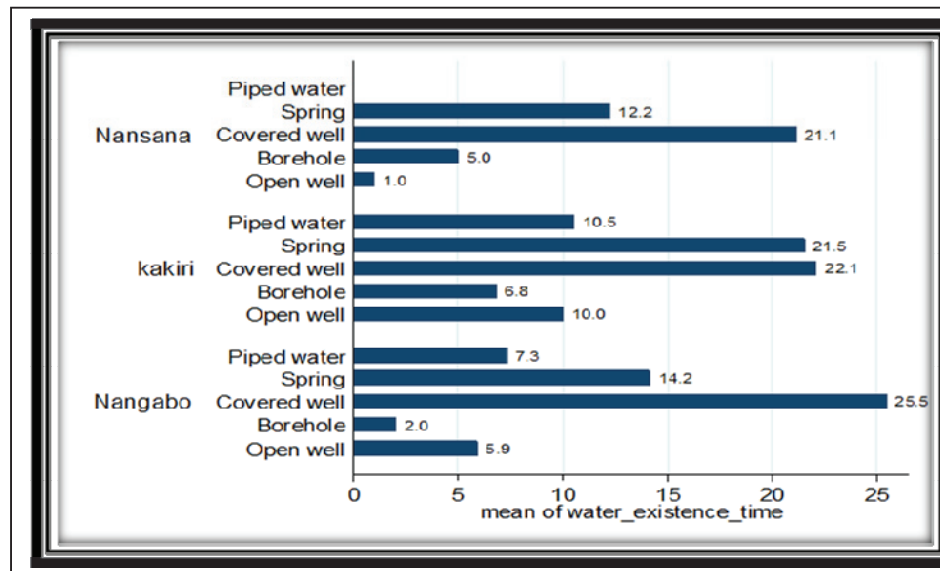


Fig 1: Distribution of Sources of Drinking Water by Sub-County in Study Location

Source: Field Survey, March 2013

Household Structures and Implications for Welfare

It is also observed that in the three sub-counties, households mainly draw their drinking water from covered wells, followed by springs, with about 21 per cent in Kakiri, 14 per cent in Nangabo and 12 per cent in Nansana. It is observed that boreholes are not well developed to provide clean water supply to the local communities as it is only about 6 per cent in Nangabo and about 2 per cent in Nansana Sub-County, who draw water from boreholes. From the interviewed respondents in Nansana Sub-County, it was found that no household had connected piped water. In this case, it is worthy noting that many respondents still draw drinking water from open water sources, which makes them more susceptible to contracting water-borne diseases in the area.

In order to assess the welfare implications of water management and household poverty in the study location, a comparative analysis was undertaken of the relationship between household structures and welfare. The household structures observed during the survey are presented in Table 2.

Table 2. Household structures observed in the study locations (percentage distribution)

House Structure	Nangabo	Nansana	Kakiri
Grass thatched ⁸	2	-	-
Mud and poles	-	3	6
Unburnt bricks	2	3	5
Burnt bricks and mud	10	8	7
Burnt bricks and cement	85	86	70
Cement bricks	1	-	11

SOURCE: Personal survey, March 2013

Findings in Table 2 reveal that the status of residential structures of the households have strong implications to overall household welfare, in terms of water harvest and processing management skills. For instance, only households that had iron sheet roofed houses got the chance to be recipients of concrete water tanks donated by AMRF, which automatically improved their welfare, in terms of access to clean drinking water. Table 2 further indicates that household welfare, connection with housing structure, is not all bad as 86 per cent of respondents in Nansana have permanent brick houses, 85 per cent in Nangabo and 70 per cent in Kakiri. In Nangabo Sub-County, only 2 per cent of the respondents stay in grass thatched houses, which implies that such households would find it extremely difficult to harvest rain water.

3.2 Time of Existence of the Different Water Sources in the Study Location

Figure 2 presents the distribution of the life span of various water sources in three sub-counties in Wakiso District. The longest period, in years, that was reported for the open wells is 26 years. This was in Kakiri, followed by 14 years for Nansana and 5 years for Nangabo, respectively. In addition, it was reported that Nangabo Sub-County has had piped water for the last 23 years, compared to 19 years for Kakiri and 18 years for Nansana. Nangabo Sub-County is reported to have acquired boreholes as far back as 19 years before the other sub-counties.

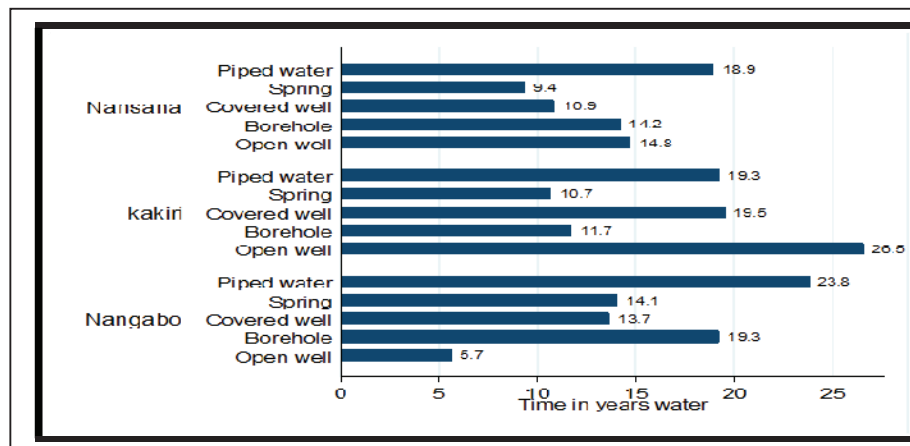


Fig 2: Distribution of Water Sources and Time Taken to Collect Water by Sub-Counties

Source: Field Survey, March 2013

Distance Travelled to Collect Water in Study Locations

Figure 3 shows that households in Nansana Sub-County travel longer distances to collect water for domestic use, compared to other sub-counties. This means that there is need to improve on water provision for domestic purposes to households in order to save on time for other household income generating activities.

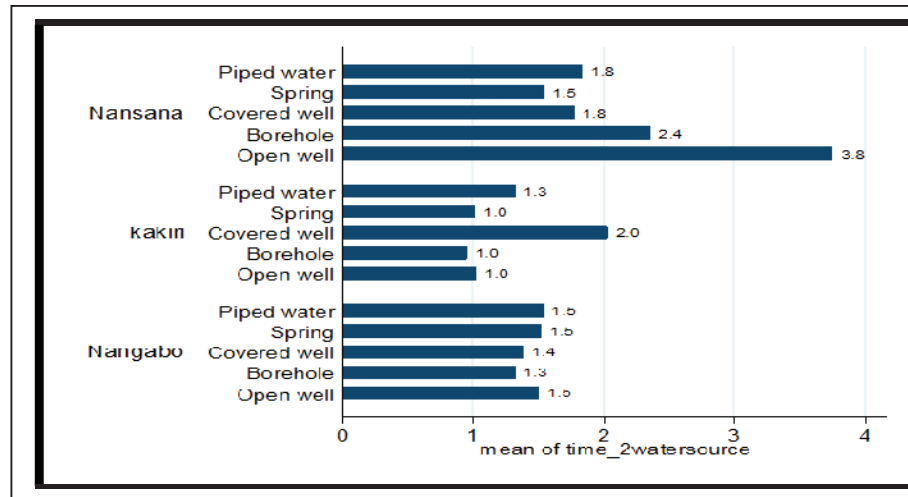


Fig 3: Average Distance Travelled to Different Water Sources Study Location

Source: Field Survey, March 2013

Households reported that individuals responsible for fetching water, mostly women and school-going children, especially girls, travel to the water sources, on average, three times a day, to collect water. The considerable labour involved in water collection comprises almost exclusively of women and children. This subsequently affects children's school performance, especially girls.

From Figure 3, it can be observed that members of households in Nansana Sub-County travel the longest distance, on average 3.4 kilometres, to access water from open wells, 2.4 kilometres to fetch water from boreholes and 1.5 kilometres to collect water from springs. In the same sub-county, piped water is not well developed as households travel an average distance of 1.8 kilometres to access piped water. Thus, there is need for the government to intensify efforts to provide more clean and safe water sources for affected communities. In addition, data in Figure 3 indicates that in Kakiri Sub-County, households travel an average distance of 2 kilometres to access water from covered wells, 1 kilometre to get water from boreholes, and 1 kilometre to collect water from springs. In the same sub-county, piped water is not well developed as households travel an average distance of 1.3 kilometres to access piped water. Furthermore, the analysis in Figure 3 indicates that households in Nangabo Sub-County travel an average distance of 1.5 kilometres to access water from open wells, piped water, boreholes, and springs.

3.3 Household Occupation in the Study Location

The analysis of occupation of households in the study location is presented in Table 3. The findings revealed that farming is the most dominant activity

in the three sub-counties with 45 per cent, 38 per cent and 36 per cent of the respondent in Kakiri, Nansana and Nangabo, respectively, engaged in farming. More individuals are engaged in business (trading activities) in Nansana (22 per cent) compared to Nangabo (16 per cent) and Kakiri (11 per cent). In regard to the driving profession, Nangabo has 20 per cent of the respondents working as drivers while Nansana and Kakiri both had 16 per cent of the respondents working as drivers.

Table 3. Household occupation observed in the study locations (percentage distribution)

Economic activity	Nangabo	Nansana	Kakiri
Farming	36	38	45
Business	16	22	11
Driver	20	16	16
Engineer	3	6	5
Teacher	6	7	15
Brick making	6	4	6
Car washing	2	2	3
House wife	10	6	15

SOURCE: Personal survey, March, 2013

The data in Table 3 reveals that between 6 and 15 per cent of the respondents are predominantly housewives. In regard to water uses, key activities identified were are brick making and car washing. The findings revealed that brick making accounts for 6 per cent in both Nangabo and Kakiri, compared to 4 per cent in Nansana while car washing is highest in Kakiri, at 3 per cent.

The findings of the analysis of household decision-making in regard to water use in the study location are presented in Table 4. The study revealed that over 50 per cent of water use decisions in all three sub-counties are made by women alone. This is not surprising because household activities are mainly taken up by women. The study findings also revealed that joint water decisions on water use is highest in Nansana Sub-County (40 per cent), followed by Kakiri (37 per cent) and Nangabo (33 per cent). Given that water is an expensive household commodity, the findings revealed that water decision- making by “someone else” is low, ranging from 1 to 2 per cent.

Table 4. Water decision making observed in the study locations (percentage distribution)

Economic activity	Nangabo	Nansana	Kakiri
Wife alone	54	56	58
Husband and wife	33	40	37
Husband alone	14	3	4
Someone else	1	1	2

SOURCE: Personal survey, March, 2013.

3.4 Patterns of Participation in Water Supply Development and Management

Access to an adequate and sustainable supply of clean water is critical in the fight against poverty and for promoting human welfare. Additionally, water is crucial to a wide range of economically important activities, from brick-making to market gardening and livestock production. Access to adequate basic sanitation remains woefully non-existent in the study area, according to the respondents. The fact that many rural water systems are not functioning properly also makes it difficult to estimate effective access to improved water supply in the study area.

The results indicate that access is skewed in the three sub-counties, especially in regard to piped water supply, while access to boreholes and springs is normally distributed in the study areas. The main reason cited by respondents is poor maintenance and insufficient cost recovery, leading to the breakdown of systems, in particular those that rely on pumping.

The different forms of water management for domestic use were observed in the study location in the three sub-counties (Table 5), which includes fencing of wells, cleaning of wells, repairing of boreholes, and use of water tanks. This reveals the commitment of the local community to have access to clean water for domestic use.

Table 5. Different water management techniques for domestic use

Economic activity	Nangabo	Nansana	Kakiri
Fencing wells	51	52	29
Cleaning of wells	12	18	45
Repairing boreholes	24	17	16
Use own water tanks	13	12	10

SOURCE: Personal survey, March 2013

Analyzing the different forms of new water management approaches by households, Table 6 indicates that 52 per cent of respondents in Nansana Sub-County participate in fencing of wells, followed by 51 per cent of respondents in Nangabo and 29 per cent in Kakiri. Cleaning of wells is more pronounced in Kakiri Sub-County (45 per cent) followed by Nansana (18 per cent) and Nangabo (12 per cent), whereas water management by repairing of boreholes is highest in Nansana (24 per cent). This implies that households in Nansana depend more on boreholes for domestic water use than households in the other sub-counties.

By use of owned domestic water tanks for water harvest, this is more dominated by Nangabo (13 per cent) and Nansana (12 per cent) sub-counties while in Kakiri sub-county, only 10 per cent of the households harvested water by use of water tanks. Given the observed water scarcity in the study location, this implies that there is urgent need for government intervention in these areas, to provide clean water for domestic use in order to minimise water-related diseases and ensure a healthy population that can more effectively fight poverty, starting from the household level.

The results show that water tariffs in the study area for piped water and harvested clean rainwater, or from the protected springs, are usually measured by jerricans (buckets), for water sold at water kiosks or public stand posts. The rural water systems managed by private individuals at the time of this survey, involved tariffs of between 400 and 500 Uganda shillings per 20-litre jerrican, equivalent to about US\$ 0.16 to 0.19 per jerrican. However, according to a World Bank report of 2008, tariffs range from only US\$ 0.25 to 0.32. In addition, to alleviate the financial burden for the poorest of the rural population, the districts keep a list of vulnerable households, such as widows and poor single-parent households, who get free access to water points when they are unable to pay the monthly subscription fees.

As noted above, women generally manage domestic water needs across the , and in most parts of the developing world. Thus women provide the pivot around which the entire sustainability paradigm of domestic water revolves. It is, therefore, of critical importance that women are involved at all the stages of planning, implementation and management of rural water supply schemes. Moreover, women's cooperation at the local level can provide a strong framework for community participation in water management systems.

3.5 Access to Agricultural Land

Access to agricultural land in the three sub-counties is depicted in Figure 6. In the three sub-counties, the findings revealed that household access to agricultural land is about 36.31 per cent in Nangabo, 35.78 per cent in Kakiri and 27.91 per cent in Nansana. This means that most of the people derive their livelihood from non-agriculture activities. This outcome can be explained by the fact that the sub-counties are located near Kampala, the

capital city of Uganda, hence considered semi-urban. Thus, the demand for water for agricultural activities is low in the study area.

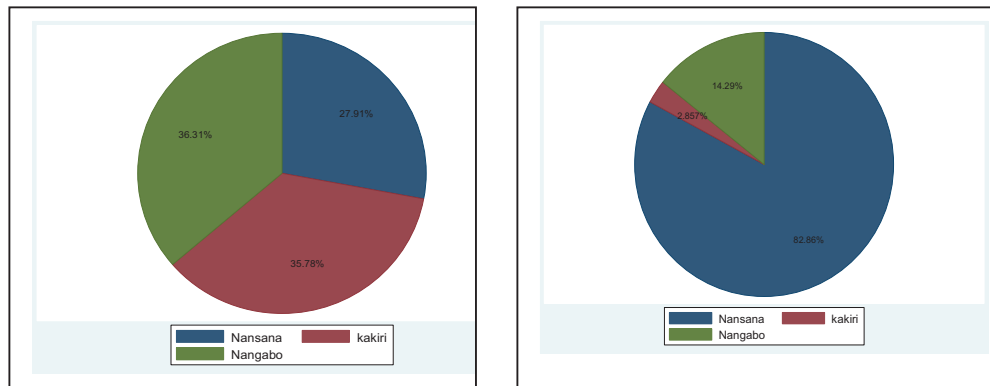


Fig 4: Access to Agricultural and Water Use for Irrigation in the Three Sub-Counties
(Authors' tabulation from personal survey, March, 2013).

3.5 Farm Irrigation in the Study Location

Another water use identified in the study location is farm irrigation. It is revealed that over 83 per cent of households in Nansana Sub-County practiced farm irrigation compared to 14 per cent in Nangabo and only 3 per cent in Kakiri. This is not surprising because Nansana being close to urban centers, households have taken up commercial farming as an alternative source of income.

The main crops that are under irrigation include flowers, vegetables and Irish potatoes. In this regard, irrigation must be emphasized if poverty is to be reduced in Uganda and elsewhere in the world. This is true in the sense that irrigation can reduce the risks associated with the unpredictable nature of rainfed agriculture in dry regions, hence increase crop production. However, all this must be combined with effective means of water control (United Nations 2011). Water control systems should also incorporate water storage (McCartney 2010, Donaghy et al. 2006), to ensure water availability throughout the various crop seasons.

3.6 Determinants of Cash and Labour for the Protection and Maintenance of Water Sources

Although the availability of safe water in rural areas in Uganda is very limited, the cost of investing in water projects, as well as their operation and maintenance, is increasing. Hence, government agencies, donors and other implementing organizations can no longer afford to meet the costs (UBOS 2010). In Uganda, the major challenge in the water supply sector is

securing resources to manage and maintain water facilities that frequently break down, and keeping water sources operating in a sustainable manner (Uganda National Water and Sewerage Cooperation 2011). This problem is coupled with an expanding urban population that entirely depends on the National Water and Sewerage Cooperation water supplies and sanitation facilities. Given the complication in management of these facilities, there have been continued water shortages due to frequent pipe bursts, theft, dumping, and blockage of the sewerage system. With these challenges, the key question is whether rural households are really willing to contribute to communal water services. Besides, can they assume management of communal water sources as their responsibility? The answers to these questions would depend on various factors.

This implies that if households are supposed to shoulder management responsibilities, effective participatory methods and support mechanisms must be formulated and implemented. This requires, among other factors, understanding the role of households in the protection and maintenance of water sources and distinguishing the basic determinants of their contributions, which is one of the major objectives of this study. To achieve this, contributions of cash and labour intended for water source protection and maintenance by individual households during the previous three months, were recorded and examined.

As noted earlier, village Local Councils (LCs) in the study locations are charged with the responsibility of collecting the set monthly contributions of cash and overseeing household labour participation for the protection and maintenance of the water sources in the areas. Accordingly, households contributed an average of Uganda shillings 40,000 per month, and on average, one labour day per month, to ensure effective maintenance and cleaning of the existing water wells and boreholes. To ensure full participation in water management, the LCs have set a fine of Uganda shillings 3,000 if anybody does not engage in manual cleaning and repairing of the water sources. Additionally, a fine of Uganda shillings 5,000 has been set if anybody collects water from boreholes for brick-making. The main reason advanced in the case of borehole water is that it is the available clean and safe water that households use for domestic uses. It is useful to note that these payments are referred to as “contributions”, rather than fees for water, to show that they are voluntary donations.

The pertinent question at this level is whether the amount that households are currently contributing, on average, can cover the costs of operation and maintenance of the various water sources available. For a water source within a LC of 500 households, users pay an average of Uganda shillings 500 every month. However, it was noted that with the current high cost of spare parts, and frequent breakdown of the boreholes, this amount is not sufficient to support the protection and maintenance requirements of the water source. It was reported by some of the respondents, through interviews, that the chairperson sometimes uses personal funds to keep the

boreholes functioning. Thus, current user contributions provide only about 70 per cent of the estimated cost, indicating that either contributions would need to be increased significantly or external support is required for adequate protection and maintenance of the existing water sources in sub-counties considered in the study.

3.7 Cash and Labour Contributions for Water Source Protection and Maintenance

A Tobit model was estimated to determine the factors that influence cash and labour contribution by households for water source protection and maintenance in the study location. Empirical results presented in Table 6 support the validity of using such a simple approach to analyze the determinants of a household's decision to participate in water management agendas, in Ugandan rural communities.

Table 6. Factors influencing household participation in new water management (marginal effects after a probit analysis)

Variables	Cash contribution model	Labour contribution model
Male household head	0.834*** (0.001)	0.283** (0.012)
Log of household age	-0.0223* (0.0676)	-0.0186 (0.126)
Log of household age squared	0.135*** (0.009)	0.137*** (0.008)
Household size	-0.102*** (0.000)	0.382*** (0.000)
Household income	0.295 (0.116)	-0.100* (0.092)
Religion: Catholics (RC)	-	-
Muslims	0.148** (0.014)	0.660** (0.0123)
Protestants	0.054** (0.035)	0.088* (0.084)
Others	-0.541 (0.819)	0.223 (0.974)
Education : No education (RC)	-	-
Primary	0.0670 (0.321)	0.053** (0.024)
Secondary	0.180* (0.053)	0.114** (0.023)
Post-secondary	0.323* (0.095)	0.623** (0.042)
Local Council Advocacy	0.184*** (0.000)	0.189*** (0.000)
Alternative water sources	-0.334** (0.008)	-0.289* (0.065)
Observations	288	284
Log likelihood	-384.60	-386.66

SOURCE: Authors' computations from the survey (2013)

P-values in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The results further confirm that most of the coefficients are consistent with the hypothesized relationships and some are statistically significant. These results have strong policy implications for the development and management of water resources in the country. Therefore, the study results are expected to help in identifying important characteristics that explain household decisions for regular and timely contributions of cash and labour by the households, for water source protection and maintenance in the study location. Additionally, the findings indicate that some of the factors should be considered in the formulation of rural water source management strategies that would enable many households to access clean and safe water supplies. Furthermore, some of the study variables appeared to be statistically insignificant, which might more likely be due to the relatively small sample size involved in the study.

The results presented in Table 6 indicate that the male-headed households positively influence cash payments and labour contributions, and this is statistically significant based on the conventional statistics. This is different from the initial proposition that women would participate more in water source management, through cash and labour contributions. However, the descriptive data shows that female-headed households are among the poorest of the households surveyed. The policy implication of this finding would be that although there could be other household obligations, the household head usually ensures that contribution to water maintenance and protection are priorities, rather than see the households go without water. Therefore, paying or working for water source management, which seeks their voluntary participation, is given due consideration in the study location.

As expected, the age of the household head appears to have an insignificant and negative relationship with both cash and labour contributions, while the age squared (more grown up) has a positive and statistically significant effect with both cash and labour contributions for water maintenance and protection in the study location. The major implication of this finding is that at an older age, household heads have more community responsibility and are fully settled, thus will extend themselves for the community than would be the case in their early years when just starting life. In addition, holding other factors constant, our estimated findings indicate that household size has a negative and statistically significant impact on cash payments but a positive impact on the labour contributions. This seems reasonable, as households with large family size are concentrated more within low-resource categories, having no excess funds to spend. However, the reason for the latter case could be that bigger households can easily afford labour for water source management as they have adequate labour for farming and other productive activities.

The study findings also reveal that household income level positively and significantly influences the payment of cash contribution for water protection and maintenance and vice versa. On the other hand, high income

levels will negatively influence the provision of labour, as expected. This result is consistent with basic economic theory, which states that an individual's demand for most commodities or services depends on income. This also implies that rich household heads, who make cash payments, have limited time to provide labour as most of their time is taken up in income-generating activities. Therefore, it is optimal or more beneficial for the poor households who have no money to make labour contribution towards maintenance and protection of the existing water sources.

Results for the two estimated models indicate that the estimated effects of household head education levels — primary, secondary and postsecondary — highly influence cash and labour contributions to water management strategies for the protection and maintenance of existing water resources compared to no education. Holding all the other variables constant, cash contributions are expected to increase by 0.29 and 0.64 units, for household head with secondary and postsecondary education, respectively. The results further reveal that household heads with secondary and primary education would enhance cash contribution by 0.07 and 0.18, and labour contributions by 0.05 and 0.11 units, respectively. This implies that there is need for the government and other stakeholders to advocate for access to free universal primary and secondary education, for all.

Holding other factors constant, the estimated effects of religion for the two models show that the effects of being from a Muslim denomination influences both cash and labour contributions, by 0.15 and 0.66 units, compared to being a Catholic. Further, being a Protestant would increase both cash and labour contributions by 0.05 and 0.08 units, respectively. Holding other variables constant, cash contributions are expected to increase by 0.44 and 0.84 units, with the LC advocating for participation in water maintenance and protection, to ensure clean water supply in the localities. This suggests that LC advocacy for clean water helps to create awareness about the opportunities in promoting protection and maintenance of water sources, and is an important component of the support framework as it positively affects the household's motivation to provide labour for water source management and cash contributions. In addition, the results reveal that alternative water sources, situated in close proximity, negatively influence both cash and labour contributions for the maintenance and protection of existing water sources. This suggests that the existence of alternative water sources such as rivers, undeveloped springs and home-made wells decreases households' willingness to make cash payments for sustainable water services.

3.8 Marginal Effects of Determinants of Cash and Labour Contributions

This section examines the factors that influence the probability that a household will make cash contributions and supply labour towards maintenance and protection of the existing water sources. The marginal effects in Table 7 reveal that the degree of household participation during

establishment of the water local council committees is the first and most crucial variable in influencing cash and labour contributions towards maintenance and protection of existing water sources. Therefore, a unit change in its value exerts the greatest effect on both contributions. An increase of the degree of participation during LC water committee implementation phase, by one unit, significantly increases cash contributions by Uganda shillings 0.44 and labour contributions by 0.23 days. Thus, it could be very useful for LCs to increase the participation of households as much as possible, to achieve increased participation in water source protection and maintenance, through increased cash and labour contributions.

Table 7. Marginal effects of determinants of cash and labour contributions

Variables	Cash contribution model	Labour contribution model
LC water committee	0.441*** (0.001)	0.273** (0.042)
Loge of household age	-0.023 (0.467)	-0.086 (0.226)
Loge of household age squared	0.135*** (0.009)	0.137*** (0.008)
Household size	-0.102*** (0.000)	0.382*** (0.000)
Household income	0.072 ** (0.016)	0.014* (0.062)
Religion: Catholics (RC)	-	-
Muslims	0.148** (0.0143)	0.660** (0.012)
Protestants	0.054** (0.035)	0.088* (0.084)
Others	-0.541 (0.819)	0.223 (0.974)
Education : No education (RC)	-0.069 (0.164)	-0.089* (0.069)
Primary	0.067 (0.321)	0.053** (0.024)
Secondary	0.180* (0.053)	0.114** (0.023)
Post-secondary	0.323* (0.095)	0.623** (0.042)
Local Council Advocacy	0.334** (0.021)	0.084** (0.014)
Alternative water sources	-0.334** (0.008)	-0.289* (0.065)
Observations	288	284
Log likelihood	-384.60	-386.66

SOURCE: Results of the estimated model by authors

P-values in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The marginal effect estimates reveal that LC advocacy is the other factor which exerts more influence on labour contributions. The analysis shows that a unit increase of the level of advocacy provided, significantly increases both cash and labour contributions by 0.33 and 0.08 units, respectively. The significance of the variables along with the magnitude of the marginal effect suggests that LC water committees should advocate and create awareness on the importance of water source management as much as possible, to achieve better participation of households through cash and

labour contributions. This empirical evidence supports beliefs commonly held by water development organizations.

The household total income is another major factor that influences the willingness of households to participate in maintenance and protection of water sources. The results reveal that an increase of household income by one additional unit significantly increases the cash contributions by 0.07 units and labour contributions by 0.01 units. These effects are very small compared to costs of water projects, although projects that increase income may become somewhat more sustaining.

4. Conclusion and Policy Implications

This study was undertaken to enable further understanding of the complex nature of innovative water management and poverty issues in rural areas. The key issues considered in this regard were water use practices, attitudes towards drinking water quality, the technical quality of water (how safe is the water) from improved water sources, the status of improved water facilities, and institutional approaches followed to enhance the sustainability of the available water resources. The study tried to identify the leading determinants of household participation in managing water supply sources and recommends possible solutions to the large-scale breakdown of water supply sources in the three sub-counties of Nangabo, Nansana and Kakiri, in Wakiso District, Uganda. To achieve this, a sample of 299 households was interviewed in the three sub-counties, using a structured questionnaire.

Both descriptive and empirical analyses, using the Tobit model estimation, were made. The major findings indicate that the gender of the household head exercises significant influence in household water management, in terms of cash and labour contributions. Water use at the household level is positively and significantly determined by household size and convenience of location. The observed outcomes also suggest that household age has a strong implication on the contribution to maintenance and protection of the existing water sources by families. However, findings revealed that household size has a negative effect on cash contributions for maintenance and protection of the existing water sources while it has a positive effect on labour contributions for maintenance and protection of the existing water sources. The descriptive evidence revealed that household members travel long distances to fetch water, which has strong implications on the household welfare, in terms of household activities and children's school performance.

To understand the role of households in the protection and maintenance of the water sources and their determinants, actual contributions of cash and labour by individual households were collected and analyzed. The estimated contributions indicate that the amounts currently provided, on average, by the households are not likely to cater for effective management of the water sources. Additionally, the empirical analyses show that

households' degree of participation in the local water committees, LC advocacy activities, and household income are the leading determinants of cash and labour contributions for water source maintenance and protection. Many of the other factors hypothesized to be important were not statistically significant, suggesting that a larger sample size may be appropriate in future research works. These results suggest that the sustainability of newly installed boreholes can be influenced by household-specific factors within the community that increase willingness-to-pay cash and willingness-to-contribute labour, useful for water source protection and maintenance. This is mainly attributed to the fact that piped water and borehole water supply is the most feasible, clean and reliable water available to households.

The findings also reveal that the degree of households' participation during the service establishment stage has significantly influenced the willingness-to-pay cash and the willingness-to-contribute labour for source protection and maintenance. It must be emphasized that the level of advocacy regarding water supply management and its consequences, such as enhanced sustainability and improved water quality, is revealed to be a determining factor of households' participation in water source management. The marginal effect of a unit increment in the level of advocacy provided by local promotion agents focusing on the benefits of water source management issues significantly increases both cash and labour contributions for water maintenance and protection. This suggests that awareness must be created through appropriate institutional support to increase the quality and sustainability of water services over time.

Likewise, the study results show that household income affects the decision of households to participate in water source protection and maintenance. This indicates the importance of recognizing that an increase in the annual household income increases the tendency of paying cash contributions and contributing labour for water source management, partly due to the ability-to-afford, a fact that one intuitively can accept. Given the number of households with a low economic status in the study sites, it may be useful to formulate mechanisms to effectively address poverty. This might be achieved through community undertakings to develop strategies that specifically target the poor as a benchmark of service delivery, and that support uses of water beyond basic livelihoods, such as micro-scale irrigation and horticultural development initiatives.

This study concludes that promoting participatory approaches, which fully involve beneficiaries according to their willingness and potentials, supported by the right advocacy and promotion efforts, can significantly contribute to sustainability of rural water sources and go a long way in alleviating poverty in both rural and semi-urban areas of Uganda. Moreover, water supply should focus on affordability and ease of access by households in the most affected areas with no clean water supplies.

Thus, understanding households and their socioeconomic, geographical and institutional settings, and aligning them with the appropriate policy frameworks, is fundamental for sustainable water management and its contribution to poverty reduction. This necessitates a high degree of flexibility in water management approaches, which considers the inherent socioeconomic differences among households.

Finally, this research has focused on household and community water management techniques and implications for poverty reduction. Further research on water management and its implications on health need to be given priority and should also cover a relatively large sample, drawn from a purely rural setting in Uganda.

The findings of this study have important implications for Uganda's water sector as well as for similar less developed countries. The critical deficiencies in community-based drinking water availability and sustainability are a major challenge to the local communities and government. The detection of these weaknesses needs to be systematic. Governments can achieve this by developing technically grounded benchmarking standards and public disclosure mechanisms, and using them to assess the relative achievements of community-based drinking water organizations over time. This approach will spur necessary improvements and increase the trust of consumers in their local providers. The demand-driven approach demonstrates that community-based water organizations can offer a service that satisfies the local people, without financial support from the government. In some circumstances, instead of subsidizing infrastructure, which can create long-term financial dependency, the central government could support local communities by providing information through public disclosure programs and periodic performance assessments. The experiences of these communities provide important guideposts as to how the United Nations, the World Bank, national governments, and NGOs can best deploy their resources, to provide clean water and sanitation to many poor households that lack clean water and basic sanitation facilities. These outside agencies can work with local communities to ensure that water systems are driven by local demand. However, communities must organize themselves to create the institutions that will maintain these systems and enforce the governing rules, long after the external actors are gone.

Notes

1. United Nations(see <http://www.globalenvision.org/library>).
2. Nick Nuttall, spokesperson of the U.N. Environment Programme (see <http://www.globalenvision.org/library>).
3. Kevin Pietersen, Director of South Africa-based Water Research Commission (see <http://www.globalenvision.org/library>)

4. (See <http://www.globalenvision.org/library>; “Shortage of Water has serious Health Consequences”
5. Jack Rose, the Rain Catcher, has been helping catch water in African villages since 2004 (<http://www.globalenvision.org/library>).
6. Women of a reproductive age (15-49).
7. Esrey and Habicht (1986) note that improvements in the quality of drinking water and provision of disposal of human waste greatly benefit child survival.
8. It is implied here that the rest of the houses are iron sheet roofed.

References

- Directorate of Water Development. 2010. *Uganda water supply atlas*. Kampala: Ministry of Water and Environment.
- Donaghy, K., Eheart, W., Herrick, E. and Orland, B. 2006. An integrated assessment of impacts of predicted climate change on the Mackinaw River Basin. In *Regional climate change and variability, impacts and responses*. Northampton, MA: Edward Elgar, pp. 79-127.
- Global Envision. 2013. Shortage of water has serious health consequences. Retrieved March 28, 2013, from <http://www.globalenvision.org/library>
- _____. 2013. Poverty in Africa linked to water management. Retrieved arch 28, 2013, from <http://www.globalenvision.org/library>
- Government of Uganda. 2000. Plan for modernization of agriculture: Eradicating poverty in Uganda. Kampala: Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and Ministry of Finance Planning and Economic Development (MFPED).
- Hope, R. A., and Gowing, J. W. 2003. Managing water to reduce poverty: Water and livelihood linkages in a rural South African context. Alternative Water Forum, May, University of Bradford, UK.
- Karikari, K. 1996. Water supply management in rural Ghana: Overview and case studies. In *Water management in Africa and the Middle East: Challenges and opportunities*, edited by E. Rached, E. Rathgeber and D. B. Brooks. Canada: International Development Research Council (IDRC).
- Kessy, F., and Aiko, R. 2008. The evolution of poverty reduction strategies in Tanzania. In *Out of poverty: Comparative poverty reduction strategies in Eastern and Southern Africa*. Dar es Salaam: Mkukina Nyota Publishers, pp. 10-32.
- Ministry of Finance, Planning and Economic Development (MFPED). 2011. The background to the budget 2011/12 fiscal year. Kampala: MFPED.
- Opio, C. 2012. Building effective drinking water management policies in ruralAfrica: Lessons from Northern Uganda. Discussion Paper Series No. 6,

- September. African Initiative and the Center for International Governance Innovation, Waterloo, Canada.
- Poverty-Environment Partnership (PEP). 2005. Poverty reduction and water management. Joint Agency Paper on Poverty Environment Partnership. UNDP. Retrieved April 1, 2013, from http://water.wiki.net/Index.php/poverty_Reduction_and_water_management.
- Sanstrom, K. 1997. Ephemeral rivers in the tropics: Hydrological processes and water resources management: A review and pathfinder. Research Report No. 8. Environmental Policy and Society. Stockholm: Linkoping University.
- Serwanga. J. 2006. The role of universities in the existing strategies for eradicating extreme poverty and hunger in Uganda. In *The role of African universities in the attainment of the millennium development goals*, edited by O. M. Mugenda, D. Mugendi, F. Q. Gravenir, E. A. Akuno, M. Otoro, K. K. Mutundu, J. Ndiripu and W. Amkaya. Nairobi: Kenyatta University.
- Sharma, N. P., Dambaug, T., Gilbert-Hunt, E., Grey, D., Okaru, V. and Robberg, D. 1996. *African water resources: Challenges and opportunities for sustainable development*. Washington, D.C: The World Bank.
- Todaro, M., and Stephen, C. 2003. *Economic development*. 8th edition. Boston, MA: Addison Wesley.
- Uganda Bureau of Statistics (UBOS). 2007. *State of Uganda's population report*. Kampala: UBOS.
- _____. 2010. (UBOS). *Uganda national household survey 2009/2010*. Kampala: UBOS.
- Uganda National Water and Sewerage Cooperation. 2005. *Uganda national water development report*. Kampala: National Water and Sewerage Corporation.
- _____. 2011. *Water supply and sanitation in Uganda*. Kampala: National Water and Sewerage Cooperation.
- United Nations Development Programme (UNDP). 2003. *Human development report 2003: Millennium development goals: A compact among nations to end human poverty*. NY: Oxford University Press Inc.
- UN-WATER/AFRICA. 2004. Sub-regional report on water resources development in North Africa. NY: United Nations Economic Commission for Africa.
- United Nations. 2011. Water for food, innovative water management technologies for food security and poverty alleviation. UNCTAD No. 4. Geneva: United Nations.
- UNDP. 2007. Water governance facility. Retrieved September 3, 2013, from <http://www.watergovernance.org/>
- World Bank. 2008. Poverty and the environment: Understanding linkages at the household level. Washington, D.C: The World Bank.

Like in many parts of the world, water resources in sub-Saharan Africa (SSA) have been pivotal for human survival, economic growth, social development, and practicing certain religion and cultural ethos. However, in spite of the intrinsic values of water, its use and management in sub-Saharan Africa has not been without limitations. The demand for water resources is increasing mainly due to rapid population growth, industrialization and urbanization and dealing with water-related issues has been complex and challenging for sustainable growth. Whilst there are various efforts by national governments, non-government organizations and communities to effectively and efficiently utilize and manage water resources, there are few comprehensive studies in sub-Saharan Africa that show the impact of the efforts on poverty reduction. Although certain reports indicate that many SSA countries lack clear vision on how water use can be harnessed with pro-poor growth and how poor communities can be capacitated to use water for poverty reduction, there are little exhaustive studies that clearly show familiar and innovative water use and management interventions followed by communities, national governments and other stakeholders, and demonstrate the challenges and successes of the same.

Cognizant of the knowledge gap, in 2012 OSSREA launched a research project on ordinary and innovative water use and management patterns and practices in SSA, with a view to generate new knowledge on unexploited opportunities that could enhance the contribution of water resources to poverty reduction. This anthology documents various issues including water use and management in agriculture especially in irrigation projects in Ethiopia, Kenya, Uganda and Zimbabwe; water harvesting in Kenya and Uganda; the role of local water use institutions in Ethiopia; and water source maintenance and protection in Uganda.



**Organisation for Social Science Research in
Eastern and Southern Africa (OSSREA)**

ISBN 978-99944-55-75-1

